EXPORT POLICY

HEARING

BEFORE THE

SUBCOMMITTEE ON INTERNATIONAL FINANCE

OF THE

COMMITTEE ON BANKING, HOUSING, AND URBAN AFFAIRS

JOINTLY WITH THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

UNITED STATES SENATE

NINETY-FIFTH CONGRESS

SECOND SESSION

PART 7

OVERSIGHT ON U.S. HIGH TECHNOLOGY EXPORTS

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TUESDAY, MAY 16, 1978

U.S. SENATE,
COMMITTEE ON BANKING, HOUSING, AND URBAN AFFAIRS,
AND COMMITTEE ON COMMERCE, SCIENCE AND TRANSPORTATION; SUBCOMMITTEE ON INTERNATIONAL FINANCE AND SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, D.C.

The subcommittees met jointly at 10 a.m. in room 5302, Dirksen Senate Office Building, Senator Adlai Stevenson (chairman of both subcommittees) presiding.

Present: Senators Stevenson, Proxmire, and Schmitt.

OPENING STATEMENT OF SENATOR STEVENSON

Senator STEVENSON. The meeting will come to order.

This is a joint hearing of the Senate Subcommittee on International Finance and the Subcommittee on Science, Technology, and Space. The work of these two subcommittees intersects today. One has been studying industrial innovation in the United States—that's the Science, Technology, and Space Subcommittee—and the other has been conducting a lengthy study of U.S. competitiveness and export policy, and in the course of these studies we have concluded that one of the principal factors to be considered in connection with the competitiveness of the United States is industrial innovation.

The United States has led the world for decades in exports of products based upon advanced technology. To a larger degree than is commonly understood, U.S. competitiveness is dependent upon more technological innovation than foreign countries have achieved.

Our technological lead has been derived from research and development supported at high levels by both industry and Government, but the situation is changing. It has already changed greatly. Government support for R. & D.—research and development—has dropped off. Private expenditures have stagnated.

Other countries have escalated their outlays for R. & D. and are becoming competitive across the board. Now the traditional U.S. trade surplus in manufactures has become a deficit, and the value of agricultural exports has declined in part perhaps because other countries have applied our R. & D. in the production of food to a greater extent. There are many factors, of course, involved in U.S.

[1] This is part 7 of an eight part series of hearings on U.S. export performance and export policy held by the Subcommittee on International Finance. The hearings form part of a subcommittee study which will serve as a basis for recommending action needed to insure the competitiveness of U.S. agriculture and industry in world markets.

competitiveness but technology is a major one, and that's what brings both these subcommittees to this hearing room this morning.

With that, I should add the International Finance Subcommittee has an additional interest in this subject because of its and this full committee's jurisdiction over export control legislation, including the Export Administration Act and its basic authority for control of technology transfers abroad. That, too, is a subject that we want to reexamine.

Senator Schmitt.

OPENING STATEMENT OF SENATOR SCHMITT

Senator SCHMITT. Mr. Chairman, I'm happy to join with you this morning in this joint hearing. I believe that it is extremely critical that we understand the historical and present relation between exports and technology. There appears to be a correlation between the decline in U.S. investments in research and development and the rapid increase in foreign trade competition. If this correlation is meaningful—and I personally believe that it is—the question then becomes: What can we do to reverse the unfavorable trends?

Now there are many economic factors which relate to the present erosion of our competitive position in the international economic arena. In addition, the perception of our military strength and will to use that strength play critical roles in how other nations will work with us or against us economically.

A few specific adverse economic trends stand out. They are: (1) an increasingly noncompetitive cost picture for manufactured goods, a subject which your Subcommittee on International Finance has dealt with in some detail; (2) an unwillingness to allow production of domestic energy to break the OPEC cartel which is controlling energy prices at this time; (3) an increasing dependence on uncertain supplies of raw materials from unstable regions of the world; (4) an increasing lack of a strategic capacity for coordination between the trade-related policies of various Federal agencies; (5) a growing inability to market our vast agricultural surpluses at fair market prices; and (6) and the subject of this hearing, the increasing deemphasis of short- and long-term research and development in this country.

This decreased emphasis on long-term research and technological development by both the private and public sectors has seriously compromised our competitive positions with respect to productivity and new export markets. Private sector investment in high-risk research and development is down because of extremely unfavorable regulatory and tax environments. Public investment in long-term research and development is down because of the generally shortsighted political views of many national priorities in the Congress.

U.S. foreign trade has traditionally depended on staying at the leading edge of technology. Our history has been one of periods of rapid technological growth followed by periods of slow decline. This has been true in the industrial revolution, shipbuilding, the agricultural revolution, rail transportation, energy production, energy conservation, management and services, air transportation, nuclear systems, electronics, and space systems. We must continually stimulate new areas of technology growth to remain on the leading edge of technological development. History shows very clearly that failure to do so will cause our economy to decline.

Mr. Chairman, I would like portions of my statement that deal with a related area of foreign technological assistance to be included at this point.

Senator STEVENSON. Without objection.

Senator SCHMITT. In the related area of foreign technological assistance, how are we going to use the unique technological revolution in which we presently find the world? Hopefully, we will not only improve the standard of living and quality of life for Americans, but also do the same for people all over this planet. It is the principal hope for creating long-term stability and friendship on this planet.

I particularly want to touch on the transfer of benefits of technology rather than the transfer of the technology itself. This is most obvious in the use of space technology, such as satellite systems. In several such areas, we already have been the primary agent for the transfer of the benefits of high technology to the world. With satellite technology we are starting to see the modern example of how we transfer the benefits of technology rather than technology itself. It is much more important for the developing world to receive the benefits of high technology than to receive the actual technology. In addition, they need a vast acceleration in the availability of low and intermediate technologies so they can feed, clothe, and educate themselves and make the necessary changes to enter the economic 20th century. In providing job-creating technologies and the benefits of high technologies, we simultaneously reduce major frictions that are causing problems in this world.

We are just beginning a major revolution in weather forecasting and climate predictions. We are beginning to admit to ourselves that the Earth is a solar engine. We therefore need to understand the fluctuations of the Sun and the influence of those fluctuations on our weather patterns. When we start to integrate monitoring the Sun with monitoring of the Earth, I think we are going to see a major breakthrough in our ability to forecast climatic phenomena, particularly, the intermediate scale of phenomena which are so economically critical to most developing nations and modern agricultural giants like ourselves.

Communications technology is another important area of benefit from high technology. The worldwide Intelsat system is a direct outgrowth of American technology. We are marketing the benefits of that technology through Comsat, but it is important to recognize that we have hardly scratched the surface in communications technology. It is also important to recognize that the approximately 100 nations that participate in the Intelsat system have become so dependent on the benefits of that technology that only one nation has ever defaulted on a bill. If they do nothing else they make sure that communications are up and functioning.

U.S. investment in research and development has declined 25 percent in the last 10 years while Germany's, Japan's, and other nations' have grown steadily. The economy is a living organism like a tree where the products and services are the fruit and basic research and development are the nourishment that sustain its growth. Our prosperity of today is based on research and development of the past. Prosperity of the future is based on our present willingness now to promote greater research and development in industry and Government. Second place is not and should not be good enough for the United States.

Now this issue cannot be addressed in isolation from other economic factors. Our export situation will improve only if we can solve the fundamental economic problems facing the Nation as a whole. When we solve our problems of inflation, excessive spending, excessive taxation, and move back toward more of a free market economy, only then will business be encouraged to invest more in the future. Solving these problems will provide an environment conducive to rapid economic growth, increased competitiveness in the world market, and expanded export of our products of technology.

Finally, Mr. Chairman, as we have discussed before, I believe it is absolutely vital that we develop a national capacity for foreign trade and assistance coordination. I do not mean a national capacity necessarily with a capital "n," I mean national in that everybody comes to an agreement on what we are trying to do in foreign trade and assistance.

Trade-related policies of the Departments of State, Treasury, and Commerce and of agencies such as the Export-Import Bank and the White House are almost completely at cross purposes. To implement this strategic trade capacity we should consider the creation of a body composed of individuals from both the private sector and the Government. This group should be chartered in some way to review the various assistance and trade programs presently in existence and recommend the initiatives which should be taken in concert by both Government and private industry to accomplish the objectives of a sound foreign trade and assistance policy.

These initiatives must provide for a development of a strategic marketing capacity for U.S. goods and services abroad. The present lack of coordination within the Federal Government of trade and assistance issues related to tax, commerce, legal technological and, in fact, patent policies is one of the most discouraging aspects of our present economic situation that has been brought to light by the hearings of both our two subcommittees.

Mr. Chairman, I am looking forward to the testimony of our witnesses. I think we have an excellent panel to start this particular endeavor, and I again compliment you for the initiative in starting these hearings.

Senator STEVENSON. Thank you, Senator Schmitt. I should mention that this is a joint initiative. I am the chairman of both these subcommittees, and Senator Schmitt is a member of both these subcommittees by coincidence, and the ranking member of the Science, Technology, and Space Subcommittee.

Senator Proxmire.

Senator PROXMIRE. I have no statement at this time.

Senator STEVENSON. Our first witness is Dr. Gary Hufbauer, Deputy Assistant Secretary of the Department of the Treasury.

Dr. Hufbauer, if you would like to summarize, we would be pleased to enter your full statement in the record.

STATEMENT OF GARY C. HUFBAUER, DEPUTY ASSISTANT SECRETARY, DEPARTMENT OF TREASURY, ACCOMPANIED BY MELVILLE BLAKE

Mr. HUFBAUER. Thank you, Mr. Chairman.

I'd like to introduce my colleague, Mr. Melville Blake, also with the Treasury Department, who is with me this morning.

Mr. Chairman, I am pleased to testify on an issue that has sparked the concerns of many in our country. I am testifying on my own behalf and not as an administration witness. However, the Treasury has attempted to look at the issues and survey the problems, and I would like to share with you this morning a summary of conclusions that we have come to so far.

[Complete statement follows:]

FOR RELEASE UPON DELIVERY
Estimated at 10:00 A.M.
May 16, 1978

STATEMENT BY GARY HUFBAUER
BEFORE THE
SUBCOMMITTEE ON INTERNATIONAL FINANCE
OF THE
COMMITTEE ON BANKING, HOUSING, AND URBAN AFFAIRS AND
THE SUBCOMMITTEE ON SCIENCE, TECHNOLOGY AND SPACE
OF THE
COMMITTEE ON COMMERCE, SCIENCE AND TRANSPORTATION
UNITED STATES SENATE

U.S. TECHNOLOGY AND U.S. TRADE PERFORMANCE

Mr. Chairman, I am pleased to testify on an issue that has sparked the concerns of many in government, industry and the academic community: a perceived decline in U.S. technological leadership and its effects on U.S. trade performance.

The scientific and technological resources of the United States are essential both for maintaining our domestic standard of living and for advancing our international trade position. We should thus carefully consider the evidence available to us in order to determine whether there has, in fact, been a decline in innovation and research, and what effect this might have on our exports.

Mr. Hufbauer is a Deputy Assistant Secretary of the Department of the Treasury. However, this statement reflects his private views and is not an Administration position.

Let me begin by reviewing the status of industrial research and development (R&D) expenditures in the United States and abroad. Research performed outside of industry has less importance in the context of international competitiveness. Medical research, for example, has obvious social value, but only indirectly affects the rate of productivity growth in American industry.

Total industrial R&D spending, that is, spending by both the Federal Government and business on R&D performed within industry, has barely kept up with inflation. Measured in constant 1972 dollars, this spending has hovered within the range of $19 to $21 billion during the last ten years.

Much of this stagnation in total real industrial R&D has been accounted for by a shrinkage in federally-funded R&D, which declined in every year but one between 1966 and 1975, averaging a 5.5 percent yearly drop. However, industry's own funding for R&D, which now accounts for two-thirds of total industrial research, increased in real terms in every year except two since 1966, averaging a 3.8 percent annual real gain over that period. Preliminary figures suggest that real increases accelerated in 1976 and 1977, averaging a 5.3 percent annual rise. As might be expected, the two periods when industry-funded R&D did not rise at all or rose very slowly were in recessionary periods, namely 1970-71 and 1974-75.

In my opinion, private industry spending on R&D probably exerts a more immediate payoff for the economy than federally-funded industrial research. Federal spending is mostly associated with Defense Department and NASA projects. Occasionally these projects create spectacular offshoots in the private economy, for example narrow and wide-bodied jets and advances in integrated circuit technology. But on the whole, I am inclined to think that private R&D spending produces findings which are more readily translated into new products and processes. Thus, I find the solid gains in industry-funded R&D encouraging, and I would contrast them with the generally somber pronouncements made about R&D trends in the United States.

For example, economists commonly attempt to show a deterioration in our national R&D effort by comparing R&D spending with Gross National Product (GNP). Industrial R&D spending as a percentage of GNP did in fact decline gradually in the last decade, from 2 percent in 1967 to 1.6 percent in 1977.

However, as an indicator of U.S. performance in industrial growth and productivity, the ratio of R&D spending to GNP is misleading. The composition of GNP has shifted over the last twenty years. In particular, the manufacturing sector, where a major portion of federally-funded and enterprise-funded research and development in the U.S. is performed, has been declining relative to total GNP. The service sector, where relatively little R&D is undertaken, has contributed a rising share of GNP. Therefore, a measure which compares R&D with GNP has become progressively more distorted because GNP is growing faster in those sectors which are less R&D-intensive.

A comparison of our R&D performance with the performance of other nations reveals that the United States still leads in absolute levels of gross expenditures on R&D, in concentration of R&D spending to industrial production, and in the ratio of R&D manpower to total population. But while the data for cross-country comparisons are weak, it appears that the United States lead is being slowly eroded, most notably by Japan and Germany.

Perhaps the most telling statistic is that, in Continental Europe and Japan, Government R&D efforts are considerably less devoted to space and defense programs that in the United States, and are much more heavily focused on industrial programs, university programs, and private non-profit research institutes. Japan for example, allots fully 78 percent of its federal R&D budget for these activities; this amounts to one-fifth of all R&D carried out in Japan. As I mentioned earlier, R&D spending for defense and space research may be less effective in stimulating growth in the economy of a nation than R&D expenditures which are more directly related to the problem of discovering new products and improving production methods.

Taken as a whole, then, the various measures do suggest that in the past decade overall R&D effort in industry for the United States has been sluggish, except for industry's own R&D financing, and that governments and firms abroad have raised their own levels of R&D activity. Yet these developments on their own do not automatically support a conclusion that the U.S. economy is weakening or that our trade position will deteriorate. Many other factors, such as the availability of capital, labor attitudes, and government regulatory policies, must be taken into account when examining trends in industrial production and trade. Product innovation and research are surely important, but they are only one contributing factor out of many.

I would like to turn now to our trade performance. Technology-intensive goods, that is goods produced by industries with above-average concentrations of applied R&D spending, comprise about 40 percent of U.S. manufactured goods exports. A recent Staff Economic Report of the U.S. Commerce Department found that this compared with only about 28 percent for Germany, Japan, France and the United

Kingdom, and somewhat lesser percentages for the rest of the OECD. Technology-intensive goods included electronics, aircraft, computers, engines, petrochemicals and drugs. The low-technology category contains such items as automobiles, construction machinery, semi-manufactures and textiles.

Our overall manufactures trade balance has fluctuated markedly in the past half-decade: in 1972 we experienced our first post-war manufactures trade deficit; in 1975 we had a record surplus close to $20 billion, and by the end of 1977 we were down to a $3.3 billion surplus. This uneveness is the cause of some concern, and has prompted fears that the traditionally strong U.S. trade position in manufactures has been eroded, in part due to a slowdown in U.S. R&D activities.

If we examine our trade balance in technology-intensive goods it appears that, prior to 1972, we had a fairly constant surplus of about $6 billion. In the past four years the average yearly surplus in this category of goods has doubled to over $13 billion. Thus, high technology goods trade has been a source of strength in our trade picture. By contrast, low-technology goods trade has largely caused the recent fluctuations in our overall manufacturing balance.

This is not to say that we have excelled with all our trading partners in all high technology products. Our experience with Japan in the consumer electronics industry, namely in televisions, radios, audio and transceiver equipment, shows some of our weaknesses. We had a $3.6 billion trade deficit in 1977 with Japan in high-technology goods, and about two-thirds of this was accounted for by imports of consumer electronics goods. Japan's consumer electronics production has quintupled in the last decade, from $2 billion in 1967 to $10 billion in 1977 by one estimate. Our trade relations with Japan have of course been a major concern for this Administration. We want to see greater U.S. exports to the Japanese market, both through a reduction in Japanese import barriers and through more energetic export efforts by American firms.

So much for past performance. Is it possible to establish a connection between levels of R&D spending in the U.S. and a possible future worsening of our trade performance? The few statistical studies that have attempted to find a correlation between R&D intensity and exports show a positive and significant relationship. These findings have been based on various definitions of export performance. For example, the Commerce Department study I referred to earlier found that the United States exported a greater share of total OECD country exports in those product groupings which had higher concentrations of R&D. Other studies, such as one undertaken by Branson and Junz, show that the U.S. trade balance is more favorable in those product groups which were more R&D-intensive.

What the studies do not show is how R&D affects trade performance independently from other important influences, such as skilled labor effects, industry-concentration effects, and scale economy effects. These other effects are frequently associated with just those industries which have high R&D levels. In addition, there are often long lag times between particular expenditures on R&D and observed effects on trade. Past studies have examined a cross-section of goods in a given time period, and have not attempted to quantify changes over time.

Finally, there is an important circularity in causation. R&D stimulates trade, but trade also stimulate R&D. Most academic analysis has focused on only one half of the loop. Yet market demand is commonly viewed as an important determinant of technological innovation in the firm, and these effects should apply to export demand as well as domestic demand.

In sum, while we can safely presume that there is a positive connection between R&D spending and exports, the relationship is not simple, nor can it be mechanically quantified. It is unlikely that larger R&D spending would improve our trade balance in the short-run, but it could well have a positive impact in five or ten years.

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However, we should recognize that certain shifts in comparative advantage away from the U.S. and in favor of other countries are probably inevitable. Since at least the early 1950s foreign markets have grown faster than American markets, and it should not be surprising that some foreign industries have likewise matured and become more competitive with U.S. industry.

Two other issues have emerged in the debate on technology and export competitiveness. First, what are the experiences of small versus large firms in technological innovation and trade? Second, does the transfer of technology and research activities abroad undermine the technological superiority and trade position of the United States?

The data are very thin for comparing the technological activity of small and large companies. One study by Gellman Research Associates composed a sample list of major U.S. technological innovations, and then examined the distribution of the innovations in five size groupings. For 1967 to 1973, firms of 100 or less employees accounted for 20 percent of the innovations, while whereas firms with 10,000 or more employees accounted for 43 percent of the total. A measure was then devised to compare major innovations per R&D dollar, by size group. Companies with 1-1000 employees produced 24 times as many innovations per R&D dollar as companies with over 10,000 workers.

The Gellman study should be interpreted with care since the underlying samples of major innovations may not accurately represent the "true" distribution of the population. The data do suggest, however, that small companies are more "efficient" with their R&D money. It should be noted that minor innovations, such as modest improvements in efficiency, were not considered. Much R&D expenditure is devoted to these improvements, and they are an important source of productivity growth. It is widely recognized that developing and commercializing a new product or process is the most costly phase of the innovation process: the rule of thumb, according to Gilpin and others, is that the cost ratios between basic research, applied research and commercial development are one to ten to one hundred. The last stage may be best suited for the large firm which has greater production, financial and marketing resources.

The trade of small high-technology companies has not been examined to my knowledge. The 1975 "White Paper" prepared under the supervision of the Commerce Technical Advisory Board on the role of new technical enterprises in the U.S. economy claims that these companies have the ability to create new job opportunities and products competitive in world markets, but the paper does not investigate their actual trade performance. As a general rule, we know large manufacturing companies in the U.S. export a higher proportion of their total shipments than do small firms, twice as much by some calculations. Using Census of Manufactures data for 1972, firms with less than 1000 employees exported an average 2.5 percent of their total shipments, whereas firms with greater than 1000 workers exported 5.7 percent of their total shipments. More recent data from U.S. corporate tax returns also support this point. Domestic International Sales Corporations (DISCs) with small corporate majority shareholders ($5 million or less in assets) accounted for 4.4 percent of gross receipts from DISC exports, while that same size category of all U.S. companies accounted for 14.6 percent of all business receipts. The figures suggest that large companies play a relatively more significant role than small companies in exports. This relationship makes economic sense, since large firms have a bigger foreign sales base to spread out the high overhead costs of exploring foreign markets.

Turning to the transfer of technology, we know less about the scope and magnitude of these transfers than we should. A basic problem is finding a satisfactory measuring stick for technology transfer. In the absence of a better figure, we are forced to rely on royalty and fee data, namely payments made for technology sales through licenses of patents, know-how and other intangible property. These data tell very little about the nature of the technology being sold. Another difficulty is that the data do not measure the technology embodied in personnel who might transfer their know-how by working overseas. A final drawback is that the fee and royalty channel includes payments for trademarks and other purposes unrelated to the transfer of technology.

In general, these data show that fourth-fifths of the royalty and fee income from overseas is from affiliated enterprises and one-fifth from unaffiliated enterprises. Fourth-fifths come from Europe, Japan, and Canada and one-fifth from the developing world. We receive ten times the amount of fees and royalties from abroad that we pay out. One notable finding from these unsophisticated measures of technology flow is the very close connection between direct investment and technology transfers.

The location and size of R&D facilities of U.S. multinational corporations is not readily known. A U.S. Government census of U.S. MNCs undertaken this year will eventually provide this information, along with data on R&D personnel overseas and other aspects of technology transfer. A 1974 study done by the Conference Board suggests that about 10 percent of U.S. MNC-financed spending on R&D was undertaken abroad in 1974, and a study done by Edwin Mansfield projects that this will rise to about 12 percent in 1980. The Mansfield study goes on to state that principal reason given by companies for undertaking R&D overseas was to answer the special design needs of overseas markets. Other reasons included lower cost of R&D talent, and the ability to monitor foreign R&D activity.

Specialized studies looking at particular industries or licensing agreements offer a better picture of what and how technology is transferred. These studies often attempt to make estimates of the impact on the economy and comparative advantage of the United States. One recent study by Jack Baranson indicates that in the twenty-five case studies he examined of transfers of technology to unaffiliated foreign enterprises, the technology released was frequently the most sophisticated and competitive technology possessed by the U.S. firms, and that these transfers could conceivably exert an adverse impact on U.S. trade and employment. However, the Baranson study also found that in at least eighty percent of the case studies there were alternative foreign sources for the technologies.

While it is probably true that the increase in foreign skill levels arising from certain transfers of technology to other countries will create greater competition for U.S. goods, it is equally true that the U.S. stands to gain from other transfers. New export markets for U.S. products may result from technology licensing agreements. Improvements in the technology may flow back to the United States. And foreign firms often locate production facilities in the United States in order to exploit their new technology here. In short, it is virtually impossible to determine the overall effect of the technology transfer process.

While the analysis is incomplete, and while definitive answers may never be possible, I believe that restrictions on the outflow of technology would not be in the national interest. The administrative aspects of a technology licensing system are truly mind-boggling. A Technology Review Board would be a boon to Washington attorneys and bureaucrats, but very costly to firms with technology to sell. Many U.S. firms rely on their earnings from foreign sales of goods and technology both to finance and to justify new research activity. If U.S. firms are forced to pass-up foreign opportunities, French, Japanese, and German firms will very probably step in. Competition from abroad can also stimulate the design of better products in the United States: I mention automobiles and consumer electronics as examples. Finally, the flow of technology goes in both directions, and the street can be blocked at one end as well as the other. In sum the generation of new technology can be stimulated in various ways by the diffusion of technology from the existing pool. Our national interest lies not in the creation of new barriers but in exposing U.S. firms to the stiff breeze of competition and fresh ideas from abroad.

I have covered much ground this morning, skimming over the surface of complex questions. One fundamental topic that I have not attempted to examine can be summarized in two questions: What is the role of R&D in furthering economic growth and productivity? And what policies should the U.S. Government adopt to increase our R&D activity? I will leave these vital questions for another occasion.

Senator STEVENSON. Thank you, Dr. Hufbauer.

We have received statements from Dr. Lawrence G. Franko of the Carnegie Endowment for International Peace, whom you mentioned earlier; also from Prof. Edwin Mansfield of the Wharton School at the University of Pennsylvania; and a letter from Mr. de Saint Phalle at the Export-Import Bank Board of Directors, all of which will be entered in the record at the conclusion of the testimony. [See p. 277.]

Now let me read from Dr. Franko's statement and get your reaction. This is in connection with your first and your last subjects; namely, Government stimulation of R. & D.

He says in his statement:

> The very lack of a clear, deterministic link between R&D expenditure input and new-product or new-process output, of course, makes R&D one of the first things to be sacrificed by "cost conscious", financially-oriented managements and government agencies in times of economic downturns or uncertainty, or when for other reasons firms and governments emphasize current consumption and payouts over future returns. Moreover, because the link is not yet subject to neat mathematical specification, technology is simply left out of the economic forecasting models on which economic policy in the U.S. is based. Yet, there can be no doubt whatsoever that U.S. exports would be vastly less—at current dollar exchange rates and with current political and foreign policy restrictions in force—had not the U.S. led the world in R&D based innovations such as the wide-bodied jet, high-thrust jet engines, precision-guidance, the xerox copier, the computer, electronic semi-conductors, satellite communications, instant-photography, penicillin, hybrid seed-grain development, genetic breeding and so forth.
>
> Contrary to the view that government never does anything except interfere with business, a very large proportion of these innovations—perhaps a majority, though I am not aware of any recent tabulation—were nurtured by the U.S. government.

He goes on—and I'll paraphrase—the Government support was critical in R. & D. funding. He adds:

> The role the U.S. Government played as a source of demand for new products and processes, and as a constant, forebearing customer in computers, semiconductors, jet aircraft, nuclear power generation, telecommunications, and even some pharmaceuticals and chemicals has for some reason rarely been emphasized or even recognized in most U.S. economics, business and history textbooks. Perhaps this role of government in so strongly underpinning U.S. comparative international advantage was too embarrassingly at odds with the nation that it was purely private enterprise that made America great.

Next:

> The seemingly underpublicized and underappreciated role that the U.S. Government has historically played in underpinning many internationally successful innovations gives special piquancy to the oft-noted dramatic decline in U.S. Government-funded R&D from its heights in the late 1960s to current levels.

If I understood you earlier, you were expressing a more conventional wisdom with which Dr. Franko takes some issue. How do you respond to those comments of his?

Mr. HUFBAUER. I agree at least 85 percent with what Dr. Franko has said, even though I haven't seen his testimony. The only point I would like to make is that much of the decline in federally funded R. & D. has been associated with falloffs in defense and NASA spending. That falloff is a matter of regret to me, but I think it is somewhat counterbalanced by the rise in private R. & D. spending in the industrial sector.

Senator STEVENSON. Private R. & D. spending?

Mr. HUFBAUER. Private R. & D. spending in the industrial sector has risen in real terms. All the figures quoted in my testimony are inflation-adjusted figures. Generally speaking, R. & D. figures are portrayed as aggregates, that is the federally funded plus private spending. The Federal portion has gone down so dramatically that the overall trend is down. But I'm not trying to take the position that the Federal contribution to American research has been small in qualitative terms. Not only is that contrary to what Professor Franko has said in his testimony, but it is also contrary to the experience of many foreign countries where the involvement of the public sector in R. & D. is proportionately greater than in the United States. That's true in Canada, Germany, and France. The modes are somewhat different than what we are familiar with, but Government involvement in the R. & D. process seems to be a fact of life.

To my way of thinking this involvement can be explained by a finding of Professor Mansfield: The private entrepreneur can ordinarily expect to recapture only a fraction of the benefits of his research and that fraction might be 20 percent or it might be 40 percent, but it's certainly less than half. That situation automatically leads to an assumption, it seems to me, of underfunding of R. & D. by the private sector and particularly underfunding in high-risk projects, and those are the kinds that you have identified in Professor Franko's testimony.

Senator SCHMITT. Would the chairman yield?

Senator STEVENSON. Yes.

Senator SCHMITT. I must run downstairs in just a few minutes, but I'm just very disturbed, Mr. Hufbauer, about something. It seems to me that you're looking at dollar figures without any critical analysis of what they mean, and as the chairman read, we are dealing with different kinds of research and development. One has to look at how is research and development categorized when listing a certain number of dollars spent. Consumer-related and regulatory-related R. & D. is a large part of what industry is investing in at the present time. Whereas, what has been shortchanged for the last 10 years is the high-risk research and development that industry finds it difficult to finance under the present tax and regulatory environment.

In between those is a transitional phase where it takes a partnership between industry and Government to carry something to the point of where industry can move with it alone. That's a new element in our society. Years ago, industry could handle almost all the appropriate research and development. Unfortunately—or maybe fortunately, depending on your point of view—we have moved into the era of high cost R. & D. in order to make any advances. That is where the Government has played its role. The list that was read there is exactly that list. It's the kind of thing that came out of high-risk research and development that almost certainly would not have been undertaken by the Federal Government under normal scenarios. I'm afraid what you have done in just looking at the numbers of dollars has avoided the breakdown of how those dollars are being spent.

Senator STEVENSON. Now if you would yield, to continue with the train of thought, between 1967 and 1977 industry funding of basic research declined an average of 1.5 percent per year in constant dollars, while Federal support of basic research dropped an average of 1 percent. Meanwhile, industry funding of applied research increased 1.1 percent. There's apparently a shift in industrial R. & D. from long-term to short-term research, from product innovation to product and process improvement; and at the same time that R. & D. as a percentage of GNP in the United States has leveled off. It is increasing rapidly in other countries, and, in fact, it may not be an exaggeration to suggest that the foreign competition is just beginning. It's taken three decades, 30 years, for the principal foreign competitors to pull themselves out of the rubble of a world war and less than that for many of the LDC's to leave colonialism behind. They are now coming on with not only high technology but also with very low labor costs.

So you have, it seems to me, as Senator Schmitt mentioned, not only declining overall figures and especially in relation to other countries, but also a changing mix in the U.S. figures, both of which strongly indicate that the erosion of technological innovation and preeminence in the United States which has been essential to our efforts to offset other advantages, including cheap raw materials and low-cost labor, is accelerating the process of erosion.

Do you disagree?

Mr. HUFBAUER. Not at all. I'm sorry if I gave the wrong impression. I think the erosion has in a sense just begun. Given the normal course of events, unless there's some fundamental change, it will probably increase in the years to come.

The emphasis I would like to give is that a program of R. & D. stimulation broadly defined—and I haven't attempted to define such a program in my testimony today—an approach of stimulation makes far more sense than the quite diametrically opposed approach of attempting to put up barriers. First, attempting to put up barriers would not work very well; and to the extent it did work, it would very probably be self-defeating.

So I don't want to leave the impression that I'm contented with the present situation largely associated with the very substantial decline in Federal funded R. & D. Nor do I want to leave you with the view that that research is somehow not significant or important to the economy. I think it is very important. There are, however, some bright spots in a generally bleak picture, and one of them is the rise in private R. & D. activity. Even if private spending is not focused on high-risk projects, from an overall economic standpoint a lot of gain comes from small nonsensational improvements in products and processes.

Senator STEVENSON. Senator Proxmire.

Senator PROXMIRE. You do seem to have a rather common, relaxed attitude toward the stagnation of R. & D. I want to ask you just about a couple areas that concern me.

One is that we have had a dropoff in constant dollars in space and defense research. We seem to have had, up until this coming year. We expect to have more appropriated for this coming year. But in terms of competition and developing industrial capacity and scientific base and so forth, it seems to me that may not be bad, depending on what we're doing with the rest of it.

As I look at where the rest of R. & D. is—Senator Schmitt mentioned the regulatory R. & D. required in the environmental area and so forth—I notice that a lot of the increase has been in energy research. We have had substantial increases in science and technology base as compared 1969 to 1976 in transportation and communications, in natural resources, in food and fiber, and a very substantial increase in health research which I'm not sure is entirely sterile from the standpoint of exports.

Have you got a breakdown that would be helpful to us—because it would seem to me that while defense R. & D. is essential, and we have to have it to defend our country—the name of the game is to have a technology that's aggressive and more competitive than our adversaries, and the space of course is an exciting area—it would seem to me that these others would be more promising in providing an export payoff because they are more explicit, more directed, and so on.

Can you give me any breakdown to indicate how we are doing in these other areas; what part of it is just a reaction to regulation and what part of it would be helpful to stimulating our exports, making us more competitive industrially?

Mr. HUFBAUER. Senator, I would like to try to supply something for the record on the specific points that you raised. It seems to me that attempts at forming the kind of nice, tight linkage that one would like for policy formulation purposes is inherently very difficult in the R. & D. area. The research manager, the Government sponsor of research, and the Congress all have to realize that research is a risky area with many dead ends. Further, the cross-connections between research in one area and findings in another are legion.

One generalization I do feel comfortable with is that Government involvement has been particularly prominent in the spectacular breakthroughs; often these breakthroughs have been offshoots of defense—and space-related activities. The more mundane, day-to-day sort of improvements tend to be more the province of industry.

The question which you and Senator Schmitt raised about how much of present research is regulatory inspired is one I would like to go back to and look at again.

In connection with some work we did on the steel industry last year, I was involved in some attempts to get estimates of how much steel capital spending was connected with environmental controls. That seemed like a number that should be easy to come by, but it was a frustrating exercise. We finally came up with some estimates, but they were by no means hard and fast. And my feeling is that in the research area the connections between regulatory push and research are, if anything, even weaker. So we will try to come up with numbers, but I think it's an area that defies easy categorization and classification (see p. 293).

Senator PROXMIRE. One of the problems that bothers me is how we get at this; how we provide more encouragement for R. & D.; what's the most efficient and disciplined and effective way to do it.

The Defense Department has a category called independent R. & D. which some of us feel has been badly abused. In fact, you take a percentage of the amount of R. & D. they do, and you give them that percentage with no strings attached and so forth. In a way, that's desirable I suppose because they can then get into areas that are more risky and that might eventually have a payoff but might not have an initial payoff.

On the other hand, it can be wasteful, very wasteful, too; and some people feel that it's kind of a ripoff. I have been very dissatisfied with the kind of response we get from the Defense Department on that, and I wondered if you had any thinking about it and, also, if you have any thinking about what we can do, no matter how we structure this assistance, whether it's with tax incentives or whether it's with direct appropriations. Just because it is an area that's somewhat remote from an immediate payoff, it's very, very hard to have an effective control, at a time when we are all very conscious of trying to hold down spending overall.

Mr. HUFBAUER. Senator, I think you have come to the nub of the problem and that is a truly troubling issue. I would like to just amplify slightly in the tax area where I previously worked.

One problem with tax incentives is that it is quite difficult to construct a line between R. & D. and various kinds of market development and promotion activities. It's a very hard line to draw and as soon as the Government gives R. & D. a more favored tax status—and there are various devices one can think of—then this line-drawing problem becomes immense. I don't think the problem is insuperable, but I do think it is a difficult one, it's a problem that will lead to abuse as companies attempt to classify additional items in a tax-favored R. & D. status.

I was involved some years ago in the section 861 regulations which deal with the allocation of R. & D. expense. There were some horror stories of the kind that you talked about that came to my attention at that time. Nevertheless, tax incentives are one approach which many countries have followed with more vigor than we have. Canada and many European countries take that approach.

The other approach which you highlight in your remarks is Government grants or Government-funded institutions. The research institution which services many private firms has been a popular and successful variant in Germany and Japan. It is, however, fraught with antitrust implications which tend to trouble people in this country. Another variant is direct Government grants to firms and universities. This requires an enlightened cadre of bureaucrats to choose projects and fund them. It can lead to the kind of problems which you highlighted with the Defense Department: there are blind alleys and boondoggles. But, if you take away the discretion and build in too many layers of review, you will kill the initiative so often required for bold innovation.

If I had my choice—and this is completely impractical—I would place far more emphasis on the names behind a project and far less on the stated objective of that project. Much is told by a past record of proven success. Certain people have ideas and are out there discovering and inventing consistently over the years. Unfortunately, I don't think our bookkeeping mentality would stand for an approach that gave each Nobel Prize winner an annual research budget of $1 million to invent and discover as he pleased.

Senator PROXMIRE. I just have one more question. Our investment abroad has been encouraged by Government programs, by OPEC, and by tax incentives, section 911, if the investment flow is taking play it's a substitute for exports. It would seem to me that would be a strong argument for discontinuing programs and incentives of that kind. Do you think that's right?

Mr. HUFBAUER. If the premise were correct, the conclusion would be correct. Senator, I have looked at this in some detail, and I think the flows are about awash. I do not think tax incentives for foreign investment have a strong pull on balance for our exports, but at the same time, I don't think they have a strong disfavorable impact in terms of killing markets that we would otherwise have had. There are cases going both ways, and it seems to me that it's practically neutral on balance.

Senator PROXMIRE. Well, if it's neutral, it seems to me there's a very strong argument for not continuing that kind of preference.

Mr. HUFBAUER. Certainly not on an export basis.

Senator PROXMIRE. Thank you, Mr. Chairman.

Senator STEVENSON. Thank you, Dr. Hufbauer.

Our next witnesses will form a panel. They are Dr. Jack Baranson, president, Developing World Industry & Technology, Inc., Washington, D.C.; Mr. H. Eugene Douglas, director, International Trade and Government Affairs, Memorex Corp., McLean, Va.; Dr. Klaus Heiss, ECON, Inc., Princeton, N.J.; and Dr. L.W. Steele, Corporate Research and Development, General Electric Co.

If they would come forward we will get started with all of their testimony and then resume the questions.

While the chairman of this committee is my captive, and he's not a champion of the space program, I might make an observation since he brought up the subject a moment ago.

Entering the space shuttle era we have an opportunity to bring home to Earth the benefits of space for remote sensing communications, including public health and education, navigation, geodesy, and so on, but there are also commercial export opportunities in the space program and even here our monopoly, our competitive position, is in danger of serious erosion.

Just last week the European Space Agency launched its first communications satellite marking the beginning of the competition between the United States and Europe for a global communication satellite market that ESA estimates will easily total $1 billion a year by 1985. Even there we are beginning to get competition and not just from the Europeans but also from the Japanese and, of course, from the Russians who very shortly will probably have a permanent manned space station.

Do you want to respond?

Senator PROXMIRE. No. I think there's no question that there are many space programs that have been extremely helpful. The space shuttle, however, I don't think is going to give us any particular competitive advantage. We are going to sell rides on the space shuttle to our competition. I think one thing about the space program is they seem to feel they have an international mission which I think is very constructive and helpful, but again, there are just parts of that program that I think we can properly economize on without losing the technology advantage.

Senator STEVENSON. All right.

Dr. Baranson, may we proceed with you, sir, and let me invite all of you to summarize your statements giving us more time for questions, and your full statements, if you can summarize, will be entered in the record.

STATEMENT OF JACK BARANSON, PRESIDENT, DEVELOPING WORLD INDUSTRY AND TECHNOLOGY, INC., WASHINGTON, D.C.

Mr. Baranson. Thank you, Mr. Chairman.

As Dr. Hufbauer pointed out, the statement I'm going to present to you is based largely on our research at the enterprise and sector level.

In the last 2 years we have carried out two major studies, one which is now nearing completion, and one on the international transfers of industrial technologies by the United States and their impact on U.S. economy, covering five industries; and a second one on the sources of competitiveness of Japanese color television and video tape recorder industry.

The remarks I have to make particularly focus on the question of competitiveness of U.S.-based production, which I think is a critical subtlety in this discussion.

That is to say, American corporations may be doing all right in terms of their earnings, but part of this may be due to precisely an internationalizing of the production function. There is also the question of design engineering for the U.S. production base.

When we come to questions of competitiveness of U.S. industry, the reasons generally cited for decline are: (1) that there are now unfavorable U.S. Government laws and regulations which impinge upon the incentives and activities of U.S. firms, and (2) that, by and large, U.S. firms are not as attentive to exports as they should be.

Our studies focus on a third area which concerns the international competitiveness of U.S.-based industry. As you know, despite the devaluation of the U.S. dollar since 1971, large segments of U.S.-based production have great difficulty in holding their own not only in world markets but also at home.

Even more disturbing is the progressive erosion of the technological underpinnings of U.S.-based industry. There has been a deterioration in the incentive to design and engineer future product generations and to design and engineer for the high-wage U.S. economy, and a tendency toward technology sharing, and shifting to offshore manufacture—as part of corporate survival for many American firms in an ever-widening range of products and components. U.S. industry and the U.S. economy face very formidable trading adversaries. Japanese enterprises have taken over production and design engineering functions, not just in the mature product range, but they are now jumping the product cycle and moving into the next generation as our studies on color television and video tape recorder equipment show. The video tape recorder—VTR—was designed and engineered in this country 15 or 20 years ago, but since then it has been completely taken over by Japanese industry—from the design and engineering to the production function. VTR equipment is now licensed to American firms for marketing under their label, and all components are produced offshore in Japan and places like Korea and Taiwan.

There is some consolation in the fact that foreign investment is coming into the United States. But in the case of assembly plants of Japanese firms in the consumer electronics industry, this is just a beachhead to service the production and technology core retained in Japan. The United States is, in effect, becoming an underdeveloped country. We are assemblers and cabinetmakers in color TV today, and the major components are, to a large extent, now manufactured abroad, and to an increasing degree designed and engineered abroad. The Japanese economy, including their enterprise system, is conducive to investments in technology, including the modernization of internationally competitive industrial plants in Japan. This stands in marked contrast to the U.S. economic environment, particularly evident in the last 7 or 8 years, and what I would call a changing U.S. corporate psyche.

If one compares the United States and Japanese economy, one is impressed by markedly different levels of capital expenditures—up to 35 percent of GNP in Japan, and down to 15 percent in the United States. Also, the Japanese economy has been virtually doubling its output every 5 years over the last 20 years, and productivity gains have advanced proportionately.

One of the most ironic things that is often overlooked is that we face an economy with an appreciating currency as compared to the depreciating dollar. Interestingly enough, an appreciating currency is conducive to a competitive environment with increasing export prices and declining import prices. This puts the Japanese firms under constant pressure to improve the efficiency of their production in order to survive at home and in the world market. In the United States we have exactly the opposite. The effect of depreciation is to buffer the industry with rising import prices, while export prices are declining. This means that American firms have not been subjected to the hot breath of competition under an appreciating currency. I think this is a very important point, and one that is often overlooked.

Reacting to the 1974 crisis, the Japanese color television manufacturers typically redesigned and reengineered their product, automated production facilities, and expanded production volumes partly by expanding even further into export markets, thereby moving down the learning curve of increased volumes and reduced unit production costs.

In the United States when you compare a cross section of similar U.S. firms, you see exactly the opposite—the retrenchment of R. & D. personnel, moving offshore with a locked-in technology, discontinuance of certain product lines, and in some cases the complete demise of the product line of the firm. U.S. firms are moving to lower risk capital and R. & D. expenditures where there is less competition and quicker returns in the profit centers. It is interesting to note in this regard that a firm like RCA, which was a leader in this field, has now acquired Hertz Rental Cars and a frozen food subsidiary.

Japanese firms are moving to the high technology range of components and products, and U.S.-based plants are being reduced to becoming assemblers and cabinetmakers in the color television field. Furthermore, 15 or 20 years ago, Japanese firms typically would buy an American product and disassemble it to determine how to manufacture it more efficiently and cheaper in Japan. You now find U.S. firms purchasing a new Japanese product, such as color televisions and cameras, only to find that we no longer have the supplier industries to produce these parts competitively.

I have three sobering thoughts that derive from the foregoing observations. First, under free trade and a depreciating dollar, the U.S. technological position has deteriorated. Our world price position has improved, but it's been a buffer behind which our technological position has deteriorated.

Second, broadly speaking, the U.S. economy may require a transitional period of technological reconstruction before resuming its competitive position in the world economy.

Third, whole segments of U.S. industry—firms that used to be once technical leaders in their field—are moving to the easier profit centers. The tendency is toward maintaining current product lines, and shortchanging long-term, new product development. This explains, in part, the contradiction of a rise in U.S. private industrial R. & D. in the face of a faltering competitiveness of U.S. industry. And most important, from all publications, there has been a fallout of design and process engineering for the high-wage U.S. economy. Increasingly, in areas like consumer electronics and certain automotive equipment, U.S. firms are moving offshore to where the wage level is lower and where they can produce more efficiently with the existing technology. The Japanese, with rising wages, do exactly the opposite. They redesign first for volume production; they retool, automate, and move toward a more capital-intensive technology that can function efficiently with the higher wage labor.

RECOMMENDATIONS

Any responsible and knowledgeable person approaches the question of recommendations with much trepidation. With this reservation in mind, I will mention three areas where I think we have to articulate public policies and refine appropriate instrumentalities.

First, we need more effective mechanisms to anticipate and adjust to technical change. You'd be surprised how little this is done. When one compares Japan and the United States in this regard, one finds the Japanese far ahead in analyzing where Japanese industry stands in the world economy, relative to foreign competitors, what the perspectives are, and how Japanese industry and the economy can adjust to a changing world, by remaining competitive, moving to the high-technology industries. This is all done in a very effective and orchestrated way in Japan. Such activities are at best fragmented and limited in the United States.

This is why Japan is successively phasing out of low-growth areas and low-productivity areas, while we seem to be moving in the opposite direction. We are moving down the product cycle in terms of product sophistication and value-added potential as in the color television case, which I mentioned earlier.

Second, Gary Hufbauer mentioned the difficulty of drawing the line in the tax incentive area between R. & D. and product development. I would go even further. We need to move away from the shotgun approach of giving R. & D. and new plant investment write-offs to everyone and develop instead more focused instrumentalities to zero in on design-engineering for the U.S. production base. We should even consider giving more than 100 percent deduction for R. & D. of this kind.

Now let me just add a brief aside here in the time allowed, which I think is important. In this country, advertising expenditures have been on a par with R. & D. expenditures for several years now—about $33 billion and $36 billion, respectively, in 1976. Our competitive position in world markets is undermined when advertising expenditures to sell the consumer what you've got replace R. & D. expenditures to improve product performance and proficiency.

By way of contrast, Japanese consumers are extremely exacting, and products in Japan have to be redesigned and reengineered constantly to meet competition and their demands. And Japanese firms are accustomed to servicing consumers in this way all over the world. I believed tax writeoffs for advertising may have undermined the technological competitiveness of U.S. industry. Congress may wish to consider reducing tax deductions for advertising, while increasing tax allowances for R. & D.

Finally, there is the question of credits to the innovative firm. For example, there is the case of Amdahl, a spinoff of IBM, which had to go to a Japanese firm, Fujitsu, and share front-end technology with them in order to obtain necessary venture capital. What may be required is a new kind of credit instrumentality.

Once again, in Japan there is a priority allocation of capital funds to the high-growth, high-productivity industries. I do believe access to credit to fund technical innovation for the U.S. economy is as important as R. & D. tax breaks.

Thank you very much, Mr. Chairman.

[Complete statement follows:]

Testimony by Dr. Jack Baranson
President, Developing World
Industry and Technology, Inc.

There are widely held views that declining U.S. exports of manufactured goods are not due so much to comparative costs and productivity of U.S.-based producers relative to foreign competitors, but rather the decline is due to negative attitudes of both business and government toward export performance. It has been argued that American firms consider exports as marginal business, and it is also alleged that U.S. Government laws and regulation inhibit or impinge upon export activities.[1/]

Although there may be some substance to both of these allegations, the research we have been doing for the U.S. Department of labor over the past two years reveals more fundamental and disturbing structural changes in the U.S. economy that have contributed to the declining competitiveness of U.S.-based industry in the world economy. Moreover, this declining share of world export trade has been continuing despite progressive devaluation of the U.S. dollar and the price advantage the revaluation of currencies has given us over our major trading adversaries in Japan and Western Europe.

Our work in the area of international transfers of industrial technology by U.S. corporations[2/] has indicated a marked tendancy on the part of a growing number of American firms to export technology as a means for maintaining world market positions and global corporate earnings. For some companies, technology sharing has become a matter of corporate survival

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[1/] See Business Week, "The Reluctant Exporter," 10 April 1978.

[2/] See "International Transfers of Industrial Technology by U.S. Firms and Their Implications for the U.S. Economy," prepared for the Office of Foreign Economic Research, Bureau of International Labor Affairs, U.S. Department of Labor, December 1976. A summary version of the report appeared in the Fall-Winter 1977 issue of Foreign Policy, "Technology Exports Can Hurt Us."

and part of their global strategy to maintain cost competitiveness and to penetrate certain markets in Eastern Europe and developing world nations. The conventional wisdom has been that these technology exports were on balance beneficial to the U.S. economy and unavoidable in the sense that unless the U.S. firm moved (or sold) its technology abroad, it would lose market shares and suffer a net decline in earnings.

There is much merit in these beliefs, but at the same time, a new set of dilemmas is posed by the corporate necessity of technology sharing and the erosion effects on U.S. employment. The arrangements place additional burdens on U.S. corporations to maintain technology at the state-of-the-art level to avoid competition from former purchasers. The implanting of an internationally competitive production capability in foreign enterprises may also adversely affect other U.S. firms in the same industry and, in general, create greater competition for U.S. industry in both foreign and domestic markets.

Another major source of erosion to U.S.-based production has been the massive movement offshore of production facilities to low-wage economies by U.S. corporations. Rather than redesign products, re-engineer processes, and re-equip plants for the high-wage U.S. economy, U.S. firms have been taking the path of least resistance, often arguing that if they did not move offshore they would lose the complete product line to foreign imports. These movements offshore have been reinforced by favorable treatment under sections 806 and 807 of the Tariff Act. Beginning with cut-and-sew operations for clothing and apparel and the less sophisticated electronic component and parts, offshore manufacture has now spread to successive generations of consumer electronics products and their major components and into such areas as complete manufacturing of major automotive components such as engines and transmissions and eventually entire vehicles.

In a more recent study which we are now completing on the color television and video tape recorder industries, we have found that the rising competitiveness of Japanese firms and the Japanese economy stand in sharp contrast to the retrenchment and faltering will that characterize American firms, many of which once were world leaders in their respective product areas. Not only have Japanese manufacturers taken over a substantial segment of the U.S. color television market (about 22 percent), they have also taken the lead in developing the new generations of consumer electronic products. The video tape recorder, originally invented and commercialized in the United States has been completely taken over by Japanese firms who now manufacture this sophisticated equipment in Japan and license U.S. firms such as RCA and Zenith to market these products in the U.S. under their own brand names.

The above described trends are taking place in two sharply contrasting economic environments -- further contributing to the widening competitive gap. In Japan there is a sustained rate of growth, a burgeoning trade surplus, and an economic environment which is conducive to expanding industrial investment in R&D and plant facilities. In the U.S., trade deficits, high rates of unemployment, and inflation inhibit bouyant growth and expansionary investment.

Capital expenditures in the U.S. are about 15 percent of GNP as compared to 35 percent in Japan and even 22 percent in the United Kingdom. The level of R&D expenditures in the U.S. also have been declining -- from more than 3 percent of gross national product in 1965 to about 2 percent in 1977, which is below that of West Germany's. But what is perhaps more significant is the quality and direction of R&D expenditures. U.S. firms have cut back on basic research, and in the consumer electronics area it is obvious that expenditures are limited largely to maintenance of existing product lines, with less and less going into developing new generations of products. The massive movement offshore by U.S. firms using state-of-the-art technology, also indicates a reduction of expenditures to design and engineer for the high-wage U.S. economy.

As competition has intensified in the world economy, the typical response patterns of U.S. versus Japanese firms stand in marked contrast. Japanese firms early in 1973-74 began redesigning sets for more efficient production and automated plants in Japan to further increase export volumes and thereby reduce unit production costs. The impressive productivity gains by Japanese firms have permitted them to absorb most of the increase in export prices resulting from the appreciating yen (U.S. prices raised 6 percent last year when yen increased 27 percent over U.S. dollar). In contrast to the progressive advance of Japanese proficiencies, U.S. firms retrenched and continued to move offshore to reduce labor costs using the same technology. (It has been difficult to obtain figures, but I would estimate that only 30 percent of the 9 million sets sold in 1977 represented U.S. production -- the remaining 70 percent are now manufactured largely in Japan, Taiwan, and Korea.)

In contrast to the persistent and aggressive technological advance of Japanese enterprise, U.S. firms have been retrenching, reducing R&D expenditures, and moving to the lower risk profit centers. RCA opted out on videotape recorder (VTR) development and is branching out into the car rental (Hertz) and frozen food (Banquet Foods) business. General Electric is joint venturing with Hitachi to attempt to recapture a share of the market and minimizing their risks by drawing on Japanese technology and production sources.

The U.S. economy can take little consolation in the reverse flow of investments into the U.S. (Sony in California, Sanyo in Arkansas, Toshiba in Tennessee and Matsushita in Illinois). It only means that Japanese firms will be able to more effectively bypass import quotas imposed under the recently negotiated Orderly Marketing Agreement, and the U.S. economy will supply low-skill labor for assembly and the low-technology range of components (cabinets and glass for picture tubes). The sophisticated range of products will continue to be imported from Japan (electronic components for chassis, picture tube, and tuners). Even more far-reaching, Japanese design engineering capabilities will be further enhanced, and U.S. capabilities will continue to decline.

The significance of the foregoing is that the competitiveness of the U.S. economy is not only threatened now in the low-technology range of industrial products from low-wage economies, but is also being challenged by a modernized and automated Japan in an ever-widening spectrum of industrial products in the high-technology range that now includes motor vehicles and consumer electronics and may eventually spread to the most sophisticated of electronic components and aircraft equipment.

It is significant to note the different signals and incentives to industry that prevail in an economy such as Japan's with an appreciating currency as compared to the U.S. where the dollar is depreciating in value. Japanese firms are compelled to invest in redesign of products and to modernize industrial plant in order to compete with the reduced prices of foreign imports and to offset the higher price of exports. In the U.S. economy, the effect of devaluations over the past seven years has been to provide an invisible tariff in the form of increased prices of foreign imports into the U.S. The consequence of this buffer coupled with reduced prices of exports, has been to shield U.S. industry from foreign competition at home and abroad and to obviate the need to improve production efficiencies through expenditures in R&D and toward new plant and equipment. In short, the Japanese economy has thrived on adversity whereas the U.S. economy has been buffered into a state of declining resiliency and competitiveness.

As for public policy guidelines in this area, two dimensions of the problem and potential resolution are indicated. One is that sustained movements in the direction of protectionism (either in the form of import restriction or further devaluation) will only exacerbate our difficulties.

The other is that we must do something to revitalize U.S. industry's incentives to design and engineer in areas we can hope to retain comparative advantage and particularly to design and engineer for U.S.-based production and our high-wage economy. Like Alice, the U.S. economy will have to run faster, if it does not choose to fall behind the rest of the world. Our economy sorely needs more effective mechanisms to anticipate and adjust to technical change. Sufficient levels of expenditures to develop and commercialize new product generations are indispensable as are the related expenditure for new plant and equipment.

It is particularly evident from a study such as ours comparing U.S. and Japanese technical response to economic change that we need more finely tuned tax and credit mechanisms to encourage and fund the innovative firm that is designing and engineering <u>for production in the U.S. economy</u> and in product areas where there is either or both growth and productivity gain potential. Incidentally, an array of instrumentalities in Japan have precisely been instituted to progressively move the Japanese economy into areas of comparative advantage and out of declining industries. U.S. tax incentives should be atuned to favor these areas, and more thought needs to be given to financial mechanisms that earmark funding for the innovative firm. Perhaps what is needed is a latter-day version of the Reconstruction Finance Corporation -- this time aimed at reconstruction of the technological underpinnings of our economy.

Senator STEVENSON. Thank you, sir. There was a graphic portrayal of the situation you described in the Washington Post this morning. I don't know if you saw it. It's a picture of a Japanese ship unloading Japanese-made automobiles in Florida in order to pick up American-made oranges.

Mr. BARANSON. Yes; I saw it too.

Senator STEVENSON. Mr. Douglas.

STATEMENT OF H. EUGENE DOUGLAS, DIRECTOR, INTERNATIONAL TRADE AND GOVERNMENT AFFAIRS, MEMOREX CORP., McLEAN, VA.

Mr. DOUGLAS. Thank you very much, Mr. Chairman.

The Memorex Corp. has made a reputation for itself as being an energetic and often an irreverent kind of company.

An archetype of the American model of a high technology company, Memorex was started in 1961 supported by venture capital. We have always sought through innovative technology to bring out better products; we have sought out export markets, increased our volume, and balanced our growth road, but the company is in a strong condition with a solid domestic and export market posture.

Memorex has been in the past, and will be in the future, very committed to its export program. In the best of all possible worlds we'd like to see our exports as product exports, but increasingly the total cost picture in the United States is making it difficult for American firms to compete, not the least reason being that many other countries in which we sell are determined to create competitive industries in areas where we are now active.

In the short term we are going to try to reduce costs in those areas which leave as much of the basic R. & D. and component manufacture as possible here in the United States, but the unit cost of production is going up faster than our cost-cutting, and it's hard to say where labor, taxes, transportation, the cost of capital, and the cost of maintaining domestic R. & D. programs is going to take us.

There are several points which I did not cover in the general statement that I gave to the subcommittee, and I would like your permission to make several statements on related subjects and to amplify them later in writing if that's acceptable.

The first of these points is the opportunities which I think U.S. firms have to extend their R. & D. capabilities through foreign sources without necessarily turning over the fruits of that R. & D. to the foreign sources.

I have in mind Japan, and to a lesser extent probably Great Britain; in both countries there appears to be a larger growth in scientifically and technically educated persons entering the job market than there are going to be opportunities for these persons to effectively contribute to their economy.

This excess intellectural capacity, if you will forgive the term, can be a kind of social and political problem to the host country, as well as a source of considerable experience to us.

Now whether we can think of this as a kind of supplemental source of R. & D. work, which might be drawn back for implementation by U.S. firms, it seems to us to be something that is interesting the computer and electronics industry, and I would recommend it for further study.

The second one is a familiar problem to everyone in this room; it certainly is to you on the committee, and that is U.S. exports abroad. The processing of U.S. export licenses continues to flow with all of the speed of subzero molasses. My company alone has lost hundreds of thousands of dollars in the past year and a half from delays in export licenses which were finally granted after the business had disappeared. We are currently working on an exemplary case of this kind: to export computer peripheral equipment to Poland—to a joint venture with an American company engaged in manufacturing tractors. OEA and DOD agree that there is no danger of diversion. The products pose no risk of exporting engineering technology. There is no question that the client is a civilian-oriented firm. The only problem standing in the way is a bureaucratic anxiety that to decide the case in the affirmative would create a precedent which the export control community doesn't know how to deal with in the future.

In our case, a West German firm, or a Japanese firm, is standing in the wings waiting to pick up the business, it is waiting to pick up the profit, and plow it back into further development of the business which will be used to further reduce our exports. Something has to be done.

We have in frustration forsworn any new idea on what to do about it. Frank Weil and Stan Marcuss, over in Commerce, and Ellen Frost at Defense, are certainly working in the right direction, but in the meantime the Congress ought to take a new look at the delays.

The third and final consideration that I wanted to offer in addition was what I call the exceptional openness of the American R. & D. and technical and scientific communities, despite a continued lack of reciprocity abroad. It is perhaps in our national character that we are open, that we welcome foreign visitors in our plants and laboratories, but it is not in our national character to continually be taken advantage of. Whether it is the Bell Labs, the Semiconductor Computer Co., medical technology, or aerospace, I feel that we in the private sector must learn and learn more rapidly than we have evidence of in the past how to be less open and more discriminating in our disclosure, our technological trends, our technological R. & D. and production innovations which are being used to supplant their American originators.

The questions which you are addressing are difficult, but they are of immense national importance. My colleagues and I want to continue to assist you as you go forward in that work. But the problems are so broad that we hope that the Congress can drive at least one stake in the near future around which we can build those programs.

Jack Baranson and Gary Hufbauer, I think intelligently indicated that the tax areas and the incentives are probably the most available and possibly the most important to stimulate innovation, to increase the motivation of the persons in industry who will be necessary to carry out that innovation.

Thank you.

[The complete statement of Mr. Douglas follows:]

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Statement of

H. EUGENE DOUGLAS
MEMOREX CORPORATION

to the

Subcommittee on International Finance
of the
Senate Committee on Banking

and the
Science, Technology and Space Subcommittee
of the
Senate Commerce Committee

May 16, 1978

Introduction

The Memorex Corporation appreciates the invitation of the Subcommittee on International Finance and the Science, Technology and Space Subcommittee to express some of our views on the subject of U.S. high technology exports. In reaching our decision to appear here today, my colleagues and I were aware that we could offer no profound observations. Certainly, we have no solutions to the serious international and domestic challenges facing U.S. high technology firms. Neither, we concluded, would we be inclined to deliver a jeremiad on things the Administration and Congress have done, or left undone, in matters of business and export policies. Still, the future of America's high technology industries and the country's export position are questions with which we are much occupied.

Since the Company's founding in 1961, Memorex has actively sought overseas markets. Today, close to 40% of our total revenue is derived from our international operations. In this success, there is no room for complacency. It has been our experience that the relationship between R&D, product innovation and export sales is an extaordinarily complex one, acutely difficult to analyze. For technology is not simply a major force in current events, it has in itself something human: not only man-made but made of men.

In his recent study of the role of science and technology in American industry, David Noble makes the observation that, although technology may be described as a composite of the accumulated scientific knowledge, technical skills, implements, logical habits, and material products of people; it is always more than this, more than information, logic, things. In thinking about the issue of high technology exports, I find it useful to remember that technology is in large measure people themselves, undertaking their various activities in particular social and historical contexts, with particular interests and.aims.

Corporate Background

Memorex is an independent manufacturer and supplier of information storage and communication products. The Company was incorporated in 1961 under the laws of the State of California and has its principal offices, laboratories, and production facilities in Santa Clara, California. Additional manufacturing sites are located in Los Angeles, California; Eau Claire, Wisconsin; Liege, Belgium; and Nogales, Mexico. Memorex maintains sales and technical offices in 54 locations in the United States and 47 cities throughout Europe, Canada, Mexico, South America and Asia. Memorex

Corporation employs more than 8,200 persons in offices and technical facilities around the world. Of the total work force , more than 70% or 6,000 persons are employed in the United States. The 1977 revenue of the Memorex Corporation was $450 million, of which roughly 40% resulted from overseas sales.

Memorex products are based on magnetic coating and electronic technologies, and our people's hard work and innovativeness have earned the Company an internationally respected name in these areas. With more than fifteen years of experience in the formulation and production of magnetic recording media and nearly a decade in the development and manufacturing of computer peripheral equipment, Memorex is one of the few companies in the world with such a combination of expertise.

Memorex's technological know-how has been focused on high growth data processing and consumer markets. For example, the major products offered by Memorex are:

Data Processing Equipment

1. Disc drives and controllers
2. Tape drives and controllers
3. Add-on memories
4. Communication controllers
5. Intelligent terminals

Data Processing Accessories

1. Computer tape
2. Disc packs
3. Flexible discs
4. Toner, magnetic cards, and other office supplies

Consumer Products

1. Audio cassettes
2. Video cassettes

ADP and Economic Growth

The data processing sector of the world economy has been characterized by exceptionally rapid growth. Data processing is now the third largest industry in the world after chemicals and automobiles.

An even more important aspect of the data processing industry is the critical role it plays in economic progress; for not only has it revolutionized the processing of numerical data, but it also occupies and will continue to occupy an important position as an administrative instrument and as a method of improving decision-making procedures. In this important respect, data processing will penetrate every area of daily life.

Computers have become a driving force of industrialized societies. At last year's National Computer Conference, the delegates heard the keynote speaker give computers credit for about 15% of the U.S. growth in per capita GNP over the past thirty years. Other United Nations studies have found a close correlation, in industrial nations, between GNP and the population of computers. The Japanese were convinced that the computer industry was a "knowledge intensive" industry which could generate new economic activity in its own right, as well as stimulate improved productivity in established manufacturing and service sectors. Given the general consensus that computers can play a major role in transferring technology, increasing productivity and finding innovative and environmentally acceptable approaches to economic growth; international demand is reasonably assured. Equally assured is the desire among the major nations of the world to have their own computer industry -- for domestic applications and for export.

The Relation of R&D to Technological Product Leadership

Increasingly, our national productivity depends on a dynamic and innovative combination of labor, capital and technology. Of these three elements, technology is probably the most important and the most difficult to predict; because, unlike labor and capital, technology cannot be applied directly. It must be commercialized, or transformed into a productive capability. In the computer industry, as with the aircraft industry, R&D is necessary to remain competitive. By any measure, the relationship between levels of R&D investment and technological product leadership is very strong. Without any empirical evidence to present, it is our opinion that the Government's unwillingness to make significant new futures investments in the U.S. aerospace industry, for one example, will work to the short-term and long-range disadvantage of U.S. technology, U.S. employment, and U.S. exports. Whatever social and political implication it may have, the past Government promotion of the aerospace industry made possible several generations of military and civilian aircraft, and spacecraft, which still figure as positive export earners. The demands which military and space applications placed on the various R&D programs stimulated the American corporate and independent entrepreneurial spirit to develop advances in metals, electronics, component miniaturization, and data processing which later found sound civilian commercial embodiment. When the Federal Government constrains its R&D activities in attempts to economize, the country may save $10 million and lose a $100 billion future opportunity.

In the private sector, R&D investments vary widely from industrial sector to sector and within a given industry. On the whole, the pressures on capital and profit are becoming a matter of continued serious concern. With inflation and government-induced costs increasing, high technology firms are under pressure to narrow their sights and select fewer R&D options for development than would have been the case only a few years ago. In a sense, I suspect that many firms are consciously under-investing in R&D because they cannot affort to do otherwise. There is another aspect to this R&D pressure. If one accepts the importance of R&D for future growth, then many smaller- to medium-size firms find that their commercial viability can be secured only in association with or as a subsidiary of a larger firm. While bigness is not in itself bad, there is a question of what the long-term implications of such a reduction might be for the U.S. For our own company, Memorex has a 1978 R&D program which contains significant increases in our in-house programs and a complementary program of acquisitions, affiliations and purchases of technology.

For a variety of reasons and contrary perhaps to prevailing myth, innovation in the computer and components industry frequently comes from the smaller firms. One certainly has seen this in California's "Silicon Valley" where the level of technological innovation has been matched by the energies of the American entrepreneurial spirit. This entrepreneurial spirit is resilient, optimistic and creative; but not impervious to the larger forces in the economy which are pushing costs up, constraining availability of venture capital, and depressing opportunities for commercialization of their technological innovations. The independent spirit of the entrepreneur is one of America's greatest assets; particularly in the context of high technology fields where bold and stubborn people, through design or luck, can push open doors to futures.

These same small firms can also have a potentially negative role in the export of commercially important, new technologies abroad. Although it is an over-simplification, one may argue that small firms are more likely to be naive in selling the fruits of their discoveries in international market than the larger firms. This is not to argue that small firms be locked-up within the U.S., but there is an exposure of perhaps unwitting leakage of commercially significant technologies.

The issue of technology transfer abroad may be one of those subjects which seem quite clear as long as we leave them alone. For better or worse, nobody will leave the subject alone; and rightly so. Unfortunately, the interest is long overdue, but by no means too late. The Japanese, French, West Germans, British and Soviets are determined to have a viable computer industry of international export quality. As such, there will be moves on both sides to seek affiliations with U.S. companies. Some of these arrangements will be motivated by access to technology, others will be directed toward access to markets. Many arrangements will be standard commercial agreements with little or no effect on American competitiveness, while others should likely be disapproved by a national level review board. The Defense Science Board's report (the so-called Bucy Report) made several suggestions which are now being studied in Washington's very special fashion.

There is little question that considerable U.S.-origin technology and production know-how leaves the country every year through the channels of foreign subsidiaries of U.S. firms or joint ventures with U.S. firms. The control of these movements is presently impossible, but some rational controls are necessary. The thought of another government administered control program in so complex an area fills many of us with disquiet. From our experience with current export controls, we fear the bad habit of bureaucrats to fight the industrial revolution before last.

Another question related to the movement of U.S. technology abroad via U.S. firms is the growing foreign investment in U.S. companies and the creation through such investment of new channels of technology export. With a few exceptions -- the recent West German purchase of Litronix, or the Japanese investment in Amdahl Corporation, for example -- we are not aware of cases of foreign investment in key high technology firms. I think few people would want to see America place special controls on that kind of foreign investment, specifically directed at suspicions that an investor was a "technology stripper." If we want technology export controls, we ought to enact a comprehensive statute, but not one directed only at foreign investment in American high technology firms. Another consideration in this matter should be an interest to improve the capital markets and investment climate so that important high technology firms do not have to turn abroad for financing. The entrepreneur or technology firm wants to bring his idea to fruition. Should he go under rather than accept Japanese or French capital? A difficult question.

SOME OBSERVATIONS ON
U.S.-U.S.S.R. ADVANCED TECHNOLOGY TRANSFER
• • •
THE COMPUTER INDUSTRY

By
H. Eugene Douglas
Memorex Corporation

May, 1978

The role of technology transfer abroad may be one of those subjects which seem quite clear as long as we leave them alone. The answers appear obvious until we begin asking questions. The issue of the transfer of technology has become a major focal point of attention for the Carter Administration, the Congress, the United Nations and other international organizations, organized labor, and the business community. As an issue for political debate technology transfer is broad, lacks common terms of reference, and will not come to an easy or early definition. One of the more complex and controversial aspects of the overall issue--the transfer of technology from West to East--has moved clearly into the forefront in 1978. The reasons for this are several, but the main considerations are these.

A. During the past twelve months, the military balance has been publicly recognized as a growing and unwelcome factor affecting the U.S.-Soviet political and trade relationship. The situation has led some analysts to comment that the U.S. reaction to the probable SALT agreement will define a watershed in U.S.-Soviet relations.[1] The Congress has heard extensive testimony that improvement in Soviet forces are continuing across the board: improvements covering the entire spectrum of weapons systems from nuclear strategic forces to conventional general purpose forces.[2] It is not that the future relationship between the two countries will turn so much on arms control issues alone as it is that the occasion for the SALT review provides a focus for new thinking and debate on a range of subjective considerations and beliefs about the origins and nature of Soviet strategic objectives and the importance of technology on the military balance. Technology warrants special consideration at this time because of widespread speculation in the United States and Western Europe that advancing weapons technology may fast alter the strategic and theater aspects of the military and political balance.

B. Both the U.S. Department of Defense and the National Security Council are now is the process of major review of policies affecting U.S. technology transfer and product sales to East Europe and the Soviet Union. In the summer of 1977, President Carter ordered a National Security Council study of a broad range of government policies with re-

[1]Colonel Richard G. Head, "Technology and the Military Balance", Foreign Affairs 56 (April 1978), p. 544. Head attributes the remark to George Kennan.

[2]U.S. Congress. Joint Economic Committee. Allocation of Resources in the Soviet Union and China-1977. Hearings before the Subcommittee on Priorities and Economy in Government. 95th Cong., 1st sess., 1977. Part 2. p. 63.

spect to technology transfer, East-West Trade, and export controls. The study is to be issued as a Presidential Review Memorandum. Pending completion of the NSC study, Secretary of Defense Harold Brown has issued "interim" guidance, dated August 1977, to the Defense establishment concerning DOD's role in support of the U.S. Government's effort to control the movement of "critical" U.S. technology, products and components to the USSR. The Secretary of Defense's guidance draws heavily on a 1976 report of the Defense Science Board titled <u>An Analysis of Export Control of U. S. Technology - A DOD Perspective</u>. The Defense Department's interim guidance, which concentrated special attention on the necessity of controlling exports of "critical technologies", has been followed by the release of a proposed "List of Critical Technologies for Export Control" and, subsequently, an abbreviated list of "very important critical technologies."

The findings of these Administration reviews may well result in significant policy changes, to be implemented by the Administration, enacted by Congress, or most likely a combination of both during the remainder of 1979 and during 1979.

C. After renewing the Export Administration Act in 1977[3], the Congress has sustained its initiatives designed to oversee the Executive Branch implementation of the recently mandated changes in the law.. Regular oversight hearings as well as hearings directed at specific topics such as multilateral enforcement of export controls and technology transfers are expected within the coming eithteen months. The Act expires in September 1979.

D. There is disagreement among the Administration, the intelligence community, the Congress, and business leaders as to what direction future U.S. export control policy should take. While disagreements on controversial subjects are by no means rare in official Washington, the lack of at least a working consensus on export control

[3] The principal U.S. export control statute is the Export Administration Act of 1969, as amended by the Export Administration Amendments of 1977 (Pub. L. 95-52), (50 U.S.C. App. 2401 et seq.).

policies covering advanced or critical technologies poses an additional burden as the Government prepares to renegotiate the COCOM list[4] of items subject to international control. The negotiations which take place at roughly three year intervals are scheduled to open in Paris in October 1978.

The current United States policy of controlling exports dates back to the beginnings of World War II when President Roosevelt was given the authority to control or curtail exports of munitions and related items in the interest of the country's defense. In a pattern now familiar from other areas of regulatory and national security legislation, the ensuing years saw an expansion of the scope of these controls as to the range of the items under control and the purposes of the export controls. Since 1947 U.S. export controls have been administered by elements of the Department of Commerce. Presently the function is administered by the Department's Office of Export Administration.

Technology exchange in East-West trade and the area of export controls impinge on other issues of foreign and national security policy in a number of important ways. It is now quite common in the more senior levels of government to face issues that require a balanced response of technical and policy judgement. Examples of cases involving technical judgement in a narrow sense would be: the design and production cost of a new series of SLBM, and the development of a radar for air combat requirements. In essentially all such cases, one also finds what Margolis

[4] The Coordinating Committee (COCOM) , an informal organization established in 1950 without formal treaty or executive agreement, is the principal international forum for controlling, in the interest of mutual security, strategic exports from member countries to the communist countries. COCOM consists of the members of NATO (less Iceland) plus Japan. The key documents for the administration of COCOM controls are lists of strategic items which it is agreed should not be shipped to communist countries. The lists are reviewed periodically and, as noted, the next revision is scheduled for October 1978. U.S. participation in COCOM is governed through the Department of State.

points out as "trans-science": questions which are not narrowly technical questions, but which require or invite treatment in technical language.[5] It is a fact of life that the technical literary among political leaders in the United States and in most NATO countries is low. And anyone familiar with decision making on national security issues is well aware of the deeply political nature of almost everything connected with the process of staffing and reaching judgments on technical considerations affecting a policy issue. This short paper deals with one such issue: the transfer of computer and computer related products and technology to the USSR. It is concerned with how the example of computers and export controls bear on other foreign policy, international trade, and national security issues.

THE SETTING

It is relevant to a consideration of the technology issue in U.S.-USSR relations that the Soviet Union is the principal military opponent of the United States and its NATO allies and will remain so for the indefinite future. The inherent faults of current vision notwithstanding, it does not seem likely that any other single power, or combination of powers, will assume this chief adversary position for the rest of the century. This observation in no way implies that armed conflict is inevitable or even probable. Put another way, given the USSR's position in international affairs as it now exists and is likely to evolve, its future and conduct is of vital importance to us.

In a closed hearing last year, CIA Director Admiral Stansfield Turner told the Joint Economic Committee of the Congress that the USSR will soon enter a period of reduced economic growth and that this will have important implications for the West. Turner said that his conclusion was based mainly on the CIA's projection of a sharp reduction in the growth of the population of working age in the 1980s,

5 Howard Margolis, Technical Advice on Policy Issues, (Beverly Hills: Sage Publications, 1973), p. 6.

coupled with anticipated Soviet bottlenecks in key commodities, especially crude oil.[6] As a result, Moscow will face new uncertainties and difficult policy options regarding energy use, imports of technology and product from the West, relations with Eastern Europe, and the size and mission of its armed forces. Among the politically more manageable options open to the Soviet leadership are limited economic reforms to increase productivity and highly selective importation of plant, equipment and technology to stimulate particularly troublesome industrial areas. Computer technology is high on the list of priority industries , and even the post-Brezhnev Kremlin would be hardpressed to downgrade its importance.

At the risk of oversimplification, it could be said that the history of modern Russia has been dominated by the need perceived by Russian leaders to catch up with the more advanced nations of the West. The importation and employment of advanced foreign technologies has been a major part of this catching up process. In the eighteenth century, Peter the Great brought in foreign technology and foreign experts by the thousands to build the economic base which would support his ambitious military and foreign policy aims. Another mass importation took place in the past century and was connected with the industrialization spurt in the 1890s. Following the Revolution, another period of major importation of foreign technology was promoted during the 1920s and, more intensely yet, the early 1930s.[7] The historical reasons and analysis of the Soviet failure

[6] U.S. Congress, Joint Economic Committee, Allocation of Resources in the Soviet Union and China - 1977, Hearings before the Subcommittee on Priorities and Economy in Government of the Joint Economic Committee. Part I. 94th Cong., 1st sess., 1977. p. 1.

[7] See the three volume work by Anthony C. Sutton, Western Technology and Soviet Economic Development 1917-1930 (Stanford, California: Hoover Institution, 1968). Vol. 2,....1930-1945 (1971). Vol.3,....1945-1965 (1973).

to internalize the creation and diffusion of technology during these periods has been well documented.[8] The failure has clearly not been total, and the Soviet leadership maintains a high level of interest and growing sophistication in selecting what technologies and processes they wish to import.

For the West, with NATO's interest in holding computer technology exports to the USSR within national security tolerable limits, a more pointed question about the Soviet advances in developing sophisticated products and techniques is how far the USSR has been dependent on imported Western technology. Although Sutton's work is not without its critics, the documentation of his arguments is impressive and persuasive. He states that:

> No fundamental industrial innovation of Soviet origin has been identified in the Soviet Union between 1917-1965....Soviet innovation has consisted, in substance, in adapting those made outside the USSR or using those made by Western firms specifically for the Soviet Union and for Soviet industrial conditions and factor patterns.[9]

Using what they have imported as a base, the Soviets have developed quite considerable skill in adapting and scaling-up, which gives the impression of indigenous achievement. In Sutton's view, the USSR has had ample time since 1928 to catch up with the West and its failure to do so is the result of weaknesses in the system, not of science, but of their capability to transform the results of science into new products and processes. Time after time, the Soviet leadership has underscored the critical importance it attaches to the attainment of pre-eminence in science and technology as an essential for victory in the struggle between the two world social systems. While Brezhnev has on occasion talked of scientific and technical progress as "one of the main fronts in the historical competition between systems," he has on other occasions made assertions that "the center of gravity in the competition of the two systems is now to be found precisely

[8] In addition to Sutton, you might consult Ronald Amann, Julian Cooper and R. W. Davies, ed., The Technological Level of Soviet Industry (New Haven: Yale University Press, 1977).

[9] Sutton, Western Technology and Soviet Economic Development, Vol. 3 (1973), p. xxv.

in this field."[10] Should we take the statement as Soviet rhetoric or as a statement of fact which guides USSR policies?

Soviet rhetoric has always appeared turgid, dogmatic, and even somewhat unreal to most Western readers. In our historic tendency to dismiss most of what the Soviets say as "rhetoric", we are prone to mistake the real message. To deftly sift the rhetoric for the real message is an exceptionally difficult task. It requires training, skills, dogged persistence, and the ability to exploit the information provided in a Soviet context. Whether one is a scholar, political leader, or businessman, the most common, subtle and pernicious error which American observers of the USSR are prone is "mirror imaging", that is, the implicit or explicit assumption that Soviet objectives are the same as ours, and that they react the same way we do to common problems and experiences, even if their system or their way of doing things is different from ours. It seems obvious to persons experienced in Soviet affairs that Western and Soviet perception of the central role of scientific and technological competition tend to differ in terms of its significance and implications. The Soviets see science and technology as bearing directly on Soviet power--economic, military-strategic and political--and therefore as a critical factor in determining the "correlation of forces" in the political and military arena for the remainder of this century. The impulse to amass military power remains a pervasive hallmark of the Soviet ruling elite regardless of generation. The dynamics of the political system favor it, and the Soviet economic system seems unalterably geared to it. The Soviets were quick to note that the scientific-technological revolution not only promotes a rapid development of the instruments of national power but also makes possible the attainment of major changes in the military and economic balance of power between the United States and the

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10 Mose L. Harvey, Leon Goure, and Vladimir Prokofieff, Science and Technology as an Instrument of Soviet Policy.(Miami,Florida: Center for Advanced International Studies, University of Miami, 1972). p. 1.

Soviet Union.

The Soviet leaders look upon science and technology as the key to the continued buildup of the material-technical base of the USSR. Because the regime's capabilities to move twoward its domestic and foreign objectives rest on this broad power base, the Politburo has tried to view Soviet technology in a reasonably objective manner. The decision to develop a new series of computers, the so called Unified Series, or RYAD series, provides one case study of a conscious Soviet decision to acquire — whether through negotiable transfer (purchase of plant, equipment, license, know-how) or non-negotiable transfer (extracting material from technical publications, direct observation by visiting specialists, or some form of espionage) --the Western know-how necessary to permit them to leap forward a decade or more in their computer industry.

SOVIET COMPUTER TECHNOLOGY - INTERNATIONAL PRECEDENTS

The effect of computer technology is pervasive in advanced industrial societies. The innovative use of these machines with powers of calculation and data storage thousands or more times greater than the human mind has been a key element of most of the significant scientific, military, and technological achievements of the last twenty years. Not only carriers of innovation into other fields, computers have undergone a series of discrete innovation in their own design and production.

The modern electronic computer is descended from the automatic calculators with electromechanical relays developed by Zuse in Berlin in the 1930s and used for aircraft design in the Second World War. The majority of the postwar innovation in computer technology has been focused on the development of general purpose digital computers.[11] A modern computer system is made up of hardware and software. The hardware comprises the central processing unit (CPU) which carries out the arithmetical and logical operations, a small internal or operational

[11] Alvin J. Harman, The International Computer Industry, (Cambridge, Mass: Harvard University Press, 1971), pp. 6-38..

memory containing data to which the processor has ready access, and a range of peripheral equipment. Peripherals include equipment for the input and output of data to and from the system; the external memory, which may be on magnetic tape, drum or disc; and a range of other equipment which can be included as required, such as a video display unit, light pens, automatic plotters, and pressure-sensitive input tablets. The software of a computer typically consists of an operating system which performs such basic functions as error detection and communication with peripherals; compilers, which translate instructions written in a high-level symbolic language into the machine code understood by the computer; and applications programs which are geared to carry out the special operations required by the user. The frontiers of each of these fundtions have been expanded enormously since the beginning of the 1950s.

The computer has been described most broadly as having developed through three generations, from vacuum tube circuitry (First Generation) to transistors (Second Generation) to integrated circuits (Third Generation) and now to large scale integration (Fourth Generation). In the third generation systems, the separate components and wiring of the circuits were replaced by integrated circuits in which all the components and their interconnections are produced in miniature on a small ceramic plate or silicon wafer. Each successive generation has made possible faster speeds of operation and larger and faster stores of memory.

SOVIET COMPUTER INDUSTRY - CHARACTERISTICS

The problems which plague Soviet industry in general are serious and highly visible in the computer sector because of its potential role in increasing the technological development of other industries and its promised contributions to improving the operation of the Soviet economy as a whole. If the industry has problems, it is not for lack of attention from the Party or from the State. The computer equipment which has been produced and was available for inspection still appears to lag Western equipment by a margin of 4 to 10 years, depending on the equipment in question. In the areas of quality control and miniaturization, it is often difficult to find the right terms of reference, for lags of 10 years in some areas are not uncommon. And in this context such periods of time become meaningless. Looking back at the historical background to the current situation, Richard Judy, writing in 1970, observed that

> Soviet computer technology started in the early fifties with a modest qualitative lag behind Western equipment. This lag lengthened into a serious gap by 1964, when Soviet technology was greatly inferior in all respects. Since 1965, with the announcement of the new Ural and Minsk systems, and the BESM-6, the gap has narrowed somewhat. Soviet computer technology remains quite inferior to the best in the West. Quantitatively, the U.S. appears to have about 50 times as many computers installed as does the Soviet Union which lags behind the United Kingdom, France, Germany and Japan, as well as the United States. The gap separating contemporary Western computer software and that employed in the Soviet Union is enormous.[12]

The data gathering for Judy's study was completed in 1968, but other research has extended the investigation of the technological level of the Soviet industry through 1973[13] with the finding that the USSR's lag in development of CPUs and peripherals was about 8 to 10 years behind the United States. Further work being carried out today by the industry-government Technical Advisory Committee structure of the Department of Commerce develops the opinion that while the Soviets have narrowed the gap in numerous areas and are working hard on improvements in others, the best that they can do is still 4 to 5 years removed from the state of the art in CPUs, and 6 to 10 years in high speed-high capacity peripheral devices. In the fast moving field of computer technology and related

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12 Richard W. Judy, "The Case of Computer Technology", in S. Wasowski, ed., East-West Trade and the Technology Gap (New York: Praeger, 1970), p. 62.

13 Robert Amann, Julian Coopers, and R. W. Davies, ed., The Technological Level of Soviet Industry (New Haven: Yale University Press, 1977), pp. 397 - 406.

national security applications, a four year lag is significant without being comfortable.

In the USSR, Party-government concern with the computer industry was growing during the decade of the 1960s, particularly with regard to its status vis-a-vis Western computer technology. From all that we can learn, there was ample reason for the Soviets to have been concerned.[14] Directives for the 1966 - 1970 Five-Year Plan approved by the Twenty-third CPSU Congress in April 1966 officially recognized the Kremlin leadership's concern about their computer industry. In the peculiar jargon of the Party, the Congress mandated a national priority to "raise the effectiveness of production on the basis of technical progress", and to "make the greatest possible use of the advanced scientific and technological achievements of foreign countries, while developing international technical cooperation."[15]

The relevance of these events may be aided if one recalls that between the launching of the Soviet Sputnik in October 1957 and the announcement of the RYAD computer series in 1969, the United States was marshalling its immense technological, innovative, and production capabilities behind the country's space program as well as in support of an ever mounting involvement in the Vietnam War. Billions of dollars and untold manyears of priority attention were being directed at improvements and new developments in electronics, components, software, and related disciplines. Without the opportunity to spread the funding of such programs over government as well as private sector users, the U.S. industry could not have financially sustained the burst of technological innovation which manifested itself, in part, in the quick introduction of third generation computer systems and advanced peripheral equipment, and the emergence of the semiconductor and component industry as a viable independent innovator in its own right.

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[14] Heather Campbell, Organization of Research, Development, and Production in the Soviet Computer Industry (Santa Monica: Rand Corporation, 1976).

[15] "Congress Directives for Five-Year Plan as Adopted," The Current Digest of the Soviet Press Vol. 18, No. 16 (May 11, 1966), pp. 4 - 6.

By the late 1960s, political pressures in the Soviet Union began to show the military-industrial elite's serious unease at the unclosed gap between the USSR and U.S. computer capabilities after a decade of unfulfilled promises and large outlays of funds. The coming Five-Year Plan was to have ambitious goals for the application of computer technology to improve industrial productivity, increase military preparedness and response, and take the first steps toward a coordinated network of computer centers located throughout the Soviet Union which could channel data into the important periodic updates to the Plan, both at the State and industrial sector levels.[16]

Of the thousands of computers in use at that time in the Soviet Union, the major groups -- MINSK, URAL, BESM, RAZDAN, NAIRI -- were neither hardware nor software compatible with one another. Worse yet from the point of efficiency, many computers within the same manufacturer's series differed due to design changes or obsolesence of earlier work. It was a nightmare of diverse and incompatible machines with broad implications on production, use, service, spare parts and long term development of systems networks within the USSR. In terms of development, computers had been designed before their applications had been established: not an uncommon occurrence due to the acute fragmentation of the research and development process. As the number of these diverse (some of them hand-tooled, one of a kind machines) computers increased, the availability of trained personnel became more acute. There was a critical shortage of programmers and service engineers. Technicians trained on the wrong equipment, or programmers schooled on inapplicable software were put into the field. The computer industry and Soviet users, already lagging behind plan and Western standards, bogged down further.

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[16] English language material is scarce covering Soviet plans for their computer networks and data service centers. Some time ago, Bruce B. Karr of Harvard University authored a paper, "Patterns and Problems of Research and Development in the Soviet Union: Computers During the 9th Five Year Plan", (Autumn, 1977). The paper was privately circulated for comment but it is not known whether it was planned for publication.

THE EDINAYA SISTEMA (ES EVM) SERIES OF THIRD GENERATION COMPUTERS

Despite the mandates of the Five-Year Plan and the Soviet government's use of various means to stimulate the progress of the computer industry, results continued to fall well short of the mark. More drastic measures were necessary. To make matters worse for the Kremlin, by the end of 1969, some of the other socialist countries with developed electronics industries, specifically the German Democratic Republic and Poland, were beginning to show signs of the will and talent to surpass Soviet efforts.[17] Thus the USSR faced the real possibility of being overshadowed by their own Eastern European allies in addition to falling ever further behind the United States and Western Europe: an undesirable trend from the Kremlin's perspective.

These considerations, along with others, appear to have motivated the Soviet government to sign, in December 1969, a multilateral agreement and separate bilateral agreements with the governments of Bulgaria, Czechoslovakia, the German Democratic Republic, Hungary and Poland for the development and production of a new line of computers to be known as RYAD, the Russian word for "series". Cuba joined the project later, in 1971. Computers in the RYAD series are designated by the Russian acronym for Unified System, "ES". Since inception, the RYAD effort is administered through the Intergovernmental Commission of Collaboration of Socialist Countries in the Area of Computer Technology. The permanent chairman of the Commission is a Soviet, M. Rakovskij, who, as Deputy Director of Gosplan, has the position from which to exercise great influence over the future of the Soviet computer industry.[18]

[17] Among the Eastern European countries, the Robotron organization in the German Democratic Republic, the Tesla group in Czechoslovakia, the ODRA series of Poland's MERA-UNION, and the Elka keyboard calculators of Bulgaria were all active at this time.

[18] In discussing the RYAD project, it may occur to some that there is no mention in this paper of the important role of the State Committee for Science and Technology (GKNT). Although the Committee is active and powerful, and plays an important role, its activities are covered in numerous publications. Heather Campbell's study cited above is a good example.

Three and a half years after the signing of the agreement, claiming that the design stage of the project was substantially completed; the Soviets organized a large exhibition of RYAD equipment in Moscow in May 1973. What few Western observers could recognize at the time was that the RYAD designs were far from complete. Much of the equipment was not operation ready. Some models were no more than empty shells, dummy machines displayed for effect. A great many (if not the majority) of the equipment specifications were not backed up with production plans and schedules geared to engineering documentation. Facilities and components had not been finalized. The division of labor among the Socialist countries, assignment of responsibilities with specific due dates, was not settled. While the exhibition was a source of pride to the Soviet hosts, and provided a useful propaganda forum for the Soviets, its major value now seems to have been the stimulation of interest among Western firms to become involved in what the Russians did not tire of describing as "the enormous untapped Soviet computer market." Whether chiefly through Soviet design or partially through Soviet planning aided by luck and timing, the stage was set for a new and important chapter in the infusion of Western technology to the USSR.

From the start, the RYAD project had a number of interesting aspects. First of all, the series is closely modeled after the IBM System/360, the pace-setter third generation computer system, and clearly the most successful computer system ever marketed. Given the severe weakness of the Soviet software capabilities, one can understand their decision to make the ES machines program (software) compatible with the IBM 360 series. Having come late to a realization of the overriding importance of software in the development and use of computers, the USSR was now interested in avoiding the enormous investment in software for RYAD. With IBM compatibility, the Soviet machines could use Western developed computer programs with no need to reprogram, and in most cases, without having to pay for their use.

The choice of the IBM 360 as a compatibility objective offered several major advantages. Although it is not known how each of these might have figured in the Soviet decision process, they are listed below in the order of their significance from a computer professional point of view.

1. Instruction Set Compatibility. Compatibility with the IBM 360 instruction set allows software written for the IBM 360 to be executed on the RYAD machines. This includes not only the operating software, but also applications programs written in languages supported by the IBM 360 software product set. It is unknown how much of IBM software is currently incorporated into the RYAD structure, but is is reasonable to assume that IBM software has been available since the inception of the RYAD project if for no other reason that there are thousands of IBM 360 installations located around the world.

2. Specification Development. The adoption of the IBM 360 instruction set and input-output (I/O) interface eliminated any debate over the external specifications of these two critical areas. The independent development of such specifications could have delayed the project by several years or more. It should be noted that the basic documents required for specification development--the Programming Reference and the I/O Interface manuals--are readily available and not subject to U.S. export controls.

3. Product Line Breadth. The success of the IBM 360 product line which offered products ranging from small to large systems, most upwardly compatible with minimal if any reprogramming required, impressed the Soviets with the thought that many of their own computer industry problems might be solved by an IBM 360 type solution.

4. Peripheral Compatibility. The use of compatible peripherals is a secondary but potentially key advantage related to RYAD adoption of the IBM instruction set compatibility. Most of the initial RYAD effort went toward CPU development, leaving the program exposed in the area of peripheral equipment. Despite their concerted efforts, and all claims to the contrary, the Soviets and their Eastern European associates in the RYAD project

have failed to provide any significant volume of a medium capacity disc drive, the work horse peripheral of third generation computer systems. The Bulgarians have mastered (through means of questionable legality in COCOM circles) the manufacture of a small capacity disc drive, and one should assume that they will succeed in moving up to the medium capacity units without undue delay, given the availability of key components or manufacturing capabilities for the components somewhere in Eastern Europe or the Soviet Union. In any case, export controls notwithstanding, standard IBM compatible peripheral subsystems from Western suppliers could be used on RYAD machines.

As a consequence of the attention created by the 1973 RYAD exhibition in Moscow and the gradual relaxation of U.S. export controls which came as one by-product of the policies of detente, the Soviets and the Eastern Europeans gained a greatly increased access to Western technology through contacts with private industry, government bodies, academic and other technical exchanges, and increased intelligence operations. Whatever good may be said about the Soviet regime,it is not troubled by scruples when there is a job to be done. From the start of the RYAD project down to the present day, the Soviets have covered the spectrum of activities — overt and covert, legal and illegal, commercial, diplomatic, and academic — to strengthen their computer industry. Using the vehicle of signed bilateral "Agreements on Exchange of Science and Technology", protracted technical and commercial discussions for deals which never come to conclusion after encyclopedic technical interogation during endless sessions, plant tours and seminars for Soviet "specialists" in the West, seminars and trade shows in the USSR and Eastern Europe, and careful scanning of the rich vein of Western technical and professional literature; the RYAD program has been supported, corrected, and brought onto its present and apparently now successful course. East European officials have admitted in private to deliberately drawing up specifications for systems and machines and then disseminating them as widely as possible to elicite the reactions of Western firms and foreign specialists. As often as not, the responses provide valuable clues to correct errors in RYAD work and give indications as to where Western technology is headed.

When necessary, Moscow has exercised its quite considerable skill in playing on the economic sensitivities of of NATO countries like France or Britain, and the political sensitivities of Austria, Finland, and Switzerland. In the past, both the U.K. and France have agreed to transfer computer and component technology which the United States export control community would not have permitted. Once confronted by the proposed transactions in COCOM, the Department of State concluded the political cost to the United States should we veto the sales would be greater than the potential breach of national security. The sales went through.

For a variety of reasons —international commercial and diplomatic senstitivities, classification of background documents, non-detection — the extensive Soviet and Eastern European espionage activities related to computer technologies and components are seldom discussed outside the government. On the whole, this is probably unfortunate. It seems incontrovertible that in instances when the United States or COCOM embargoes a legitimate sale, and when the item in question is critical enough, the Soviets do not waiver on principal to pay whatever price is necessary to secure the goods. If a product, component, or document cannot be secured by more or less direct and open means, and if the pricrity is high enough; then the Soviet or Eastern European intelligence agencies are engaged to carry through. As with other espionage activities, it doesn't have to be a Soviet citizen in the publicly active role. It could be a Bulgarian, a Czech, a Pole, or an American.

It is impossible to say precisely how many computers or what technologies have been smuggled into the Soviet Union in support of the RYAD program, but one case may illustrate the sort of things which have gone on. Several years ago, the West German authorities arrested a local Stuttgart data processing executive, Peter Lorenz, and charged him with several violations of the statutes regarding illegal exportation of data and computer equipment to the USSR. Lorenz and his associates had not only smuggled an IBM 360/40 and an IBM 370/145 out of Germany to the USSR by disassembling the machines and carrying the parts out in trunks; they had provided follow-up services on technical documentation and even engineering services while the Soviets were digesting their computer acquisitions.[19] The Bulgarians, not to be outdone, have also been active in the special operations end of the RYAD project. Their tasks seem to have been concentrated in securing technology and supplies of components for disc drives and magnetic heads. In 1977, a U.S. citizen and a West German national were arrested in Florida where they were later tried for attempted espionage. Among the items on their shopping list for shipment to the German Democratic Republic was computer peripheral technology and engineering documentation. Eastern European and Soviet interest in unauthorized exports of equipment and technology is significant enough to occupy serious FBI attention and to require the full time services of a special office for investigations and compliance within the Department of Commerce's Office of Export Administration.

The relevance of RYAD related espionage and extra-legal actions is not political. In that area, Soviet actions do not surprise. Rather it raises good questions about whether the Soviets have in fact developed a viable computer technology independent of the West or whether they are sustaining its momentum by further infusions from abroad. One recalls Sutton's skepticism of Soviet indigenous innovation in the production of non-military items and his comment on the USSR's skill in copying, importing, "reverse engineering", scaling-up, and so on. The RYAD case is further complicated by recent Soviet confirmations of the RYAD II project, a family of more advanced computers which will serve as the follow on to the RYAD I. Just as the RYAD I family is patterned after the IBM 360 series, the RYAD II is said to be patterned on the IBM 370 series. Accurate and authoritative information on RYAD developments is practically nonavailable, and published and verbal sources have to be accepted until proved inaccurate.

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[19] W. David Gardner, "Reexporting: How Peter Lorenz Shipped IBM Hardware to Russia", Datamation (January, 1975). See also Umni Glaz, "The Silicon Curtain," Computer Decisions (September, 1977), pp. 30-34.

The Soviet and Eastern European capabilities to innovate and further develop their respective computer sectors independent of significant product and technology imports from the West have trade and policy implications for the United States and NATO.

THE LINK BETWEEN COMPUTER EXPORTS AND NATO

From the experience of the past twenty years, it seems generally to be the case that America's NATO allies are less than enthusiastic about the continued maintenance of a system of coordinated export controls, and that the United States incurs political costs by maintaining these restrictions. For the United States, export controls have been based on generally long term considerations of national security, although economic and trade considerations do play a role in export license decisions. This is not the case in Europe, where it appears that the NATO members tend to trust the United States to hold the line on really important strategic trade items leaving the field open for them to secure short term commercial advantages in the Soviet and Eastern European market. Usually it is the European COCOM partners who advocate relaxation of controls. In the case of computers, however, there is an interesting, and likely temporary, departure. For the upcoming COCOM list review in October 1978, it is expected that some of the NATO allies will express their concerns that the relaxation of controls not be allowed to proceed too quickly in the computer fields. These concerns have both trade and military aspects.

On the commercial side, Europe is well aware that the U.S. enjoys a wide majority of advantage in the marketplace for large systems and high capacity computer peripheral equipment. At the moment however, the Europeans are suppliers of a large share of the Soviet Union's total (and declining) imports of computers: mostly smaller or specialized systems. The Western European countries are concerned that a relaxation of controls, by releasing the upper end of the technology spectrum where U.S. product exports have a competititve advantage, would cause Western European exports to be replaced by those from the United States. Such fears as now exist have been heightened by the expansion of the RYAD program with its base in IBM and U.S. oriented technologies and suppliers.

A second COCOM concern centers on military aspects of the East-West relationship. The unremitting and impressive advances which the Soviet Union has achieved in its military poition, and the enhancements which these imply to the Warsaw Pact forces, have unsettled some NATO officials for the first time in more than a decade. To a very considerable extent, General Alexander Haig has made his point that the Allies must increase their concern with preparedness and defense: the theater balance is shifting in favor of the Soviet forces and determined actions are necessary to counter and reverse the trends. Soviet plans, centered on their concepts of "military cybernetics", to extend computer technology to troop control, battlefield intelligence, and communications functions is causing the Europeans to reevaluate their relatively liberal past policies covering computer related products, component, and technology sales to the East.

THE EFFECTS OF EXPORT CONTROLS: THE U.S. PERSPECTIVE

Computers and computer technology have a value as items in international trade, and they also have military implications that warrant governmental restrictions on their sale to actual or potential adversaries. Export control policy involves broad and difficult questions concerning timing and "trade-offs" with respect to trade with both communist and noncommunist countries. The stakes are high and the issues extremely complex and acutely difficult to analyze. To the extent that advanced technology and products with military applications reach the Soviet Union prematurely and diminish U. S. lead-time with respect to military capabilities, national security is compromised and the "leakage" must be countered by increased outlays for U.S. and NATO defenses. Yet technological developments cannot be contained indefinitely, and in most cases perhaps the most that can be achieved is some delay in these developments reaching the USSR. This concern with the "leakage" of technologies and a suspicion that our lead in military significant technologies vis-a-vis the Soviet Union may be slipping are reappearing themes in hearings before the Congress and in Administration studies such as the one now underway within the NSC.

The essential policy problem of controlling exports, whether of products or technologies, is to structure and manage the tradeoff between the benefits we derive from such trade and the major implications which the trade has for a real or potential adversary. You must always answer the key question of what effects the export will have on the adversary? Suppose our exports can go to two different sectors of the Soviet economy (military or civilian) and can have two different kinds of effects in either sector ("resource-freeing" or "capability-enhancing").[20] In dealing with the Soviet Union, it always difficult and sometimes quite impossible to estimate with precision how a given export will free or enhance internal resources and how such freed or enhanced resources affect military capabilities.

Our recent experience tells us that in light of the volume of U.S. trade, the breadth of our national involvement in advanced technologies, and the lack of technical sophistication of most government officials involved in export control decisions; it is not practical to advocate a case by case review of each transaction for its military implications and economic benefit.

In 1976, when the Defense Science Board released its report on U.S. export control policies, one of the key objectives was to stimulate debate on an effective national policy to cover export control of the advanced technologies without erecting as a by-product a cumbersome new bureaucracy. The key findings and recommendations of the group are quite

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[20] Robert E. Klitgaard, National Security and Export Controls, (Santa Monica: Rand Corporation, 1974), pp. v-vi.

relevant to the subject and may be summarized as follows:

A. If the United States is to maintain its lead in strategic technologies, exports of know-how concerning "critical technologies" and certain products related to them must be effectively controlled. The categories of exports which should receive closest scrutiny are: (1) arrays of design and manufacturing know-how; (2) "Keystone" manufacturing, inspection and test equipment; and (3) products accompanied by sophisticated operation, application or maintenance know-how.

B. While the more active mechanisms for technology transfer (e.g., turnkey construction projects and sales and licensing of technology) must be tightly controlled, product sales usually do not result in the transfer of current design and manufacturing technology and normally need not be so tightly controlled.

C. Tactics to protect U.S. lead time in strategic technologies must depend on the technological position of the United States as compared to that of the prospective receiving country. When both the United States and the receiving country are on the same <u>evolutionary</u> track with respect to a given strategic technology, export could be approved. However, when the United States' position results from a <u>revolutionary</u> gain, export controls should focus on protecting all key elements of this gain.

D. Controls on product sales should emphasize their intrinsic utility rather than commercial specifications and intended end-use. Deterrents such as end use statements and safeguards should not be used to control applications of design and manufacturing know-how. Deterrents generally should not be relied upon to prevent manufacturing equipment from being used for military purposes. While deterrents may have some value with respect to product sales, they should be supplemented by effective enforcement techniques against violations.

E. Key elements of technology that constitute revolutionary gains should not be released except to COCOM countries, and any COCOM nation that allows such technology to be passed on to any communist country should be prohibiited from receiving further strategic know-how. The United States should release to neutral countries only those technologies it would be willing to transfer directly to communist countries.

F. The United States should pursue policies to strengthen the COCOM system.

G. The Department of Defense should develop policy objectives and strategies for the control of specific high technology fields, and these should include the identification of the most important elements of technology, including critical processes and key manufacturing equipment.

A central theme of the Defense Science Board's discussion, and one which is being carried through all current deliberations on national export policy is that the impact of technology on national security may be revolutionary or incremental -- depending on how it is exploited -- and the military balance may be changed by improvement of older technology as well as by the development of the new. With reference to the recent developments in the Soviet computer industry, it appears that the facts and Soviet actions can support the view that the RYAD achievements are largely imitative and not innovative in the usual sense of the term. A knowledge of the international computer industry and long years of working with the USSR support a second opinion that the Russians seem to be casting the RYAD computer industry in the organizational and operating mold of their only sustained technological success: the Soviet aircraft industry. Regardless how they acquired the base technologies and skills to launch the RYAD program, once the base is established, the Soviets can apply their proved formula of centralized research and development, vertical integration of supply, incremental design changes, and extensive product development and testing. In short, they can do all the things with their reformed computer industry which they have failed to accomplish in the past. Obviously, the aircraft industry and the computer industry are not the same. They have different methods, different dynamics. In any event the experiment would be more in keeping with Soviet character than taking a risk at losing what momentum has been built in the RYAD program. Finally, what is the implication for export control? Despite the fact that the RYAD is based on what is "old" technology in the U.S. context, it is a "new" technology in the Soviet environment and through incremental applications is likely to contribute to an expansion of Soviet capabilities in the computer industry, including the application of computer techniques to small and medium scale military systems. As such, the developments could constitute a military enhancement and should be subject to strict U. S. and NATO export controls.

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Senator STEVENSON. Thank you, sir. Dr. Heiss.

STATEMENT OF DR. KLAUS P. HEISS, ECON, INC., PRINCETON, N.J.

Dr. HEISS. Thank you, Mr. Chairman. I will briefly summarize my written remarks. They comprise four points.

The first point is that the economists have found it very difficult to measure the impact of R. & D. on the national economy. Essentially, there are two schools of thought, one that attributes a major share of the productivity increase in the U.S. economy since World War II indeed to R. & D. and innovation. There is another school of thought in the economic community which attributes the same increases in productivity mostly to capital investments, labor, and to a lesser extent to R. & D. and innovation.

The difficulty is to define an aggregate series, like GNP—gross national product—and then to trace changes in GNP by relating these to productivity time series. I believe this is an unproductive approach to making a case for or against R. & D.

This uncertainty, however, has led, at the Federal level, to a very serious lack in Federal funding of R. & D. I think one contributing factor is this disunity in the economic community, its inability to make up their minds as to the effect of R. & D. domestically, and as I will show later, also with regard to international trade.

The right approach to assess the impact of R. & D. is at the sector level, or the project-by-project level. For example, studies by Mansfield, studies done by us, again and again indicate the great contributions that R. & D. have made, whether financed privately or by the Federal Government.

The second point is that due to this difficulty of relating domestic GNP to R. & D. ECON recently initiated a research effort in trying to tie R. & D. expenditures of the United States, including Federal R. & D. expenditures, to the international trade position of the United States by specific commodity classes—the standard industrial classification—SIC—codes. In my written testimony, I have summarized in graphical form some of the preliminary findings on pages 93 and 94.

Fifteen industry classifications are shown there, grouped into three areas. One, on the lower left, comprises essentially non-R. & D. intensive industries. A broader area in the center of the page, and finally, one specific industry, aerospace, way up in the right-hand corner of the picture are also shown.

Plotted on the horizontal axis are the gross exports of each of these industries as a percentage of sales, also listed on the preceding table; so it is a relative measure of export intensity of each industry.

Plotted on the vertical axis of the same figure are research and development expenditures, again as a percentage of sales—in order to get around distortions of absolute scale.

What one finds is that R. & D.-intensive industries are typically the most export-intensive and world trade-oriented sectors of the U.S. industry; non-R. & D.-intensive industries make very little contribution to the competitive position of the United States in world trade.

One industry, or sector, of the economy that is missing from this page is agriculture, which again I consider to be a highly technology-intensive and R. & D.-intensive industry. The public's perception may be that farmers and farming are not technology or R. & D. intensive, a wrong perception.

Senator SCHMITT. Do you have an estimate of where the agricultural industry would fall?

Dr. HEISS. No; we are trying to pin down these figures for agriculture; they are difficult to come by. If we succeed in 6 months we hope to include that in this figure. It would just be nice to know where precisely agriculture is in this context.

Senator STEVENSON. But agricultural commodities are the largest export——

Dr. HEISS. Yes; with aerospace.

Senator SCHMITT. But the difficult thing is estimating what is the R. & D. components of costs. Is that correct?

Dr. HEISS. Correct. Because agricultural R. & D. is done by nonprofit institutions, the Department of Agriculture, et cetera. It is a very diffuse R. & D. community in agriculture. Universities make significant contributions, and the Agricultural Extension Service, as well as others. Should we include all of those costs, or which part?

The second figure—page 94—is equally revealing. It is certainly not done by design. I mean these are the facts as of 1975, and they are very similar over the past 20 years.

This figure shows the net trade of each of these industry groups for the United States for 1975; what one finds are that where exports exceed imports, these industries are nearly—I wouldn't say exclusively—but nearly exclusively R. & D.-intensive industries. Again aerospace is a major strong component of that export picture. The non-R. & D.-intensive industries are again in the lower left-hand side—negative—portion of this figure. For example, non-R. & D.-intensive industries do run typically a balance-of-trade deficit.

Now it is very difficult to statistically relate R. & D. to export activities of each of these industries. We have performed, I think, statistically very meaningful exercises. In addition, we have also tried to relate Federal funding of R. & D. performed by industry to this export picture, and our results today indicate that the relationship is even stronger, that whatever correlation we found in cross sectional data over the past 18 years between R. & D.-intensive industry and exports, if we only use federally funded R. & D. in those industries and relate it to their share in export activities, the correlation is significantly stronger than that of just total R. & D. performed by each industry.

This contradicts some of the testimony today, that the case for Federal R. & D. funding is weak, at least that is how I interpreted one of the comments made earlier. I think what is happening here is all too quickly the formation of a consensus by the economic community along the lines that Government is inefficient, hence federally funded R. & D. is inefficient, and if one just left it to industry they would make vast use of R. & D. resources. I think the case of the United States in aerospace, in particular, contradicts that quick finding.

One should be much more careful before accepting such general, negative findings. I think they are just not correct.

Senator SCHMITT. Just so we are clear on the chart, you are saying on page 93, that you get the same result if you study Federal R. & D. as a percent of investment or as a percent of——

Dr. HEISS. Percent of sales. R. & D. as a percent of sales, and federally funded R. & D. as a percent of sales.

Senator SCHMITT. Any ratio of R. & D. to something would give you the same result?

Dr. HEISS. Correct. That leaves out about $8 billion of Federal R. & D. which cannot be allocated to industry, because it is performed intramurally or by nonprofit institutions. That is not to say that the knowledge doesn't trickle down to industry, because these people go from industry into such establishments and back again to industry.

So there is an additional factor here that is actually not reflected in the figures that we are looking at, because we cannot allocate these funds to specific industries.

Now the third point I would like to make concerns what has happened to Federal R. & D. funding. I do have a breakdown of what Senator Proxmire asked for before on page 96. If one looks at Federal R. & D. funding in constant dollars for the past 20 years, grouped by 5-year periods, and expressed in second quarter 1972 dollars, one finds that total funding of defense R. & D. has dropped from $50 billion in the first 5 years of the sixties, $50 billion again in the second 5 years of the sixties, to $42 billion in the first 5 years of the seventies, and now to $41 billion in the second 5 years.

These are absolute dollars. All we do is take out the effect of inflation. If our posture in defense is that technology is the leading edge, and not quantities of tanks and airplanes, how can we maintain that posture with a 25-percent real cutback in these activities? These are not annual observations, these are numbers aggregated over 5 years each, 10 years in the sixties, and 10 years in the seventies.

Contrary to these adverse developments in defense, and even more adverse in space, civilian funding of R. & D. by the Federal Government has significantly increased in the same timespan. It has moved from $11 billion for the first 5 years of the sixties, to now—projected—$31 billion for the 1975–79 fiscal year period.

Total federally funded R. & D., again in constant dollars, is around $100 billion for the 1965–69 period; this has dropped back to $80 to $82 billion for the 5 years from 1975 to 1979.

More appropriate than constant dollar figures, I believe, are numbers that try to relate the relative effort on research and development activities to other activities in the economy. One such measure, I truly believe, is the percentage of GNP we dedicate to R. & D. This is shown in table 12a of my testimony. Here indeed I think lies the major weakness of the current Federal R. & D. budgeting process, policy process, if not innovation process: We find that defense R. & D.—in these relative terms, that is, how much of our total GNP each year do we spend on defense-related research questions—has been cut from 1.3 percent, roughly, to 0.6 percent; the relative emphasis we give to defense R. & D. has been cut in half. We would expect at least a level number in our defense posture, if technology based and not on number of tanks and number of planes.

Civilian R. & D. has increased; it has increased by about 50 percent in these relative terms. Space R. & D. has significantly dropped; in fact, if you compare it to the second half of the sixties, space R. & D. has dropped by a factor of 3.

The total funding of R. & D. by the Federal Government has dropped from 1.9 percent of GNP to 1.2, or 1.23.

This has not changed in fiscal year 1979 despite the special analysis submitted by OMB on R. & D. funding. The only thing that has changed is the funding of basic research. If one puts in an expected rate of inflation of 6 percent for the year 1979, I think a low number, the funding of R. & D. by the Federal Government has stayed level. It has not increased.

Senator STEVENSON. The real increase in basic research is all in DOD, is it not?

Dr. HEISS. Well, a lot of it; yes.

Now the fourth point: What would be my recommendations? One, I believe that Congress should seriously assess whether the Federal funding of R. & D. should not go back to levels of the 1960's. This would mean, in fiscal year 1979, a difference of between $10 and $15 billion of funding by the Federal Government, funding, not performance, of research. This cannot be done overnight. It has to be done over a period of years. But the issue is the current level of funding by the Federal Government, is it the right one or was the sixties level the right one? In addressing that question I would not exclude too quickly and too flippantly the opportunities that space research offers in that connection, for instance the space shuttle, mentioned earlier, the application of using space technology to the economic and industrial advantage of the United States. Some of the configurations are familiar to the U.S. Senate on what the United States could do in worldwide communications by using space as a new base, which is akin to what A.T. & T. is today doing for the United States domestically. It is this order of magnitude expansion of space technology over the next 20 and 30 years that can or cannot come about. The United States as part of its Federal policy should define such goals and pursue them. It is not Appollo, it is no longer prestige, it is pursuit of economic interests, things the United States can do that no other nation will be able to do for the next 5, 10, maybe even 15 years that is at the heart of new space R. & D. initiatives. That is one reason why we should do it.

Second, I do agree with the earlier remarks that privately funded R. & D. in the United States is taking a wrong turn. I would propose, following up on your hints, Mr. Baranson, an idea which is successfully being tried in Germany, the formation of R. & D. venture companies with special tax features. The process works as follows: The innovator or innovators have to go before the tax authority, the local one, and state what new idea or technology they want to finance, pursue, and then if successful, implement. The tax authorities then coordinate the approval or nonapproval of that venture with the Ministry of Research. If it is on the list of worthwhile things and if the proposal submitted looks halfway technically decent—not proven necessarily, but has a chance—then the venture is approved; one consequence of such approval is that the venture companies can depreciate up to 2.5, or 3 times, the original investment made into the venture before it is subject to corporate income and other income taxation.

Now is this a subsidization? I think it misconstrues the very nature of innovation, which I believe is additive to what we do, that is, innovation is a "nonzero sum game." Those who innovate add to the wealth of the Nation. The only question here is when does the Federal Government come and dip into the company till and take out money. Is it immediately after the first dollar of profit shows up, or is it 2 or 3 years downstream when the venture is successful?

Now if the investment is a loss, the loss occurs to the investors, one does not take away that risk, or what economists like to call "revealed preference." Whether it is a good idea or not, it is their money; there are no consequences to the U.S. Treasury if the venture is a loss; the investors have lost their money, they are out of it.

It is only when the investment pays off that the researchers are allowed to have a threefold depreciation of the original investment, before they become subject to income taxation.

Familiar to you may be OTRAG, the space transportation enterprise developed with private funds in Germany, which is essentially such a scheme. I could not envision an OTRAG in the United States. It would be an impossible venture under current U.S. tax and economic regulations.

I would like to conclude my remarks with one last observation. The depreciation and devaluation of the dollar is a very dangerous approach to solving economic problems of the United States in the world economy. It is like New York City coming in and trying to devalue "New York currency" as a solution to its problems. There comes an end to that road for a country that aspires to reserve currency status. The United States has to initiate substantive programs, and one is in research and development. If not, the position of the United States will become untenable. There are today hundreds of billions of dollars held by foreign corporations, banks, and governments—at tremendous economic benefit to the United States—which, if they don't continue to accept dollars as a reserve currency, will come back to haunt us; we can only overcome this with a strong foreign trade position by the United States, and one area to maintain or regain that position is an inspired, forward-looking Federal research and development program.

Thank you.

[The complete statement of Dr. Heiss follows:]

R&D AND THE U.S. TRADE POSITION

Testimony by Klaus P. Heiss, President, ECON, Inc.

Presented to

Subcommittee on International Finance Committee

on Banking, Housing and Urban Affairs

and the Science Technology and

Space Subcommittee of the Senate Commerce Committee

Tuesday, May 16, 1978

Dear Chairmen:

Thank you very much for the opportunity to present my views to the Subcommitees on International Finance, and of Science, Technology and Space. In my testimony today I will (1) outline some of the difficulties of assessing the impact of R&D on the national economy, (2) report on preliminary results on the possibly strong link between R&D, including federal R&D funding, and the competitive position of the United States in world trade, (3) highlight the severe cutback of federal funding of research and development efforts in the United States in the 1970s, a trend that has not been reversed in fiscal year 1979 and (4) suggest a new initiative to create R&D venture corporations that after review and approval by federal R&D institutions as to the significance of their proposed research--would be allowed to depreciate a multiple (e.g. 3 times) the initial investment before being subject to federal (corporate) income taxation.

My testimony is based on the considerable work that ECON has done in the general area of evaluating economic impacts of R&D related ventures of private industry and the government. Among others we have (1) developed a communications specific econometric model to assess the likely impact of telecommunications R&D on the U.S. economy*, (2) developed innovative approaches to assess the value of global information systems** and (3) performed numerous economic assessments of federal R&D and technology efforts. It is based on this experience and involvement that I feel deeply about the issues raised below.

1.0 The difficulty of assessing the economic impact of R&D on the U.S. economy. The expected economic impact of R&D is the advancement of the level of productivity, and hence the improvement of economic efficiency. To the degree that one economic system is more efficient than others, this should also generate positive balance of trade effects, in the sense of increased export competitiveness. However, in assessing R&D effects on economic systems, it would be first necessary to measure the level of

*Philip Abram and Kan-Hua Young "The Effects of R&D in the U.S. Telecommunications Industry", Astronautics and Aeronautics, May 1977 and ECON, Estimation of the Demand for Public Service Communications, December 1976.

**David Bradford and Harry Kelejian "The Value of Information for Crop Forecasting in a Market System: Some Theoretical Issues", The Review of Economic Studies, October 1977 and David Bradford and Harry Kelejian "The Value of Information for Crop Forecasting with Bayesian Speculators: Theory and Empirical Results", The Bell Journal of Economics, Spring 1978.

productivity as a function of time and then try to trace R&D initiatives to changes in productivity over time. Since R&D spending is but one of many factors which can lead to an increase in the productivity level, it is also necessary to isolate the effects of R&D from other factors. Theoretically, this analysis can be performed for the domestic impact of R&D at the national (or micro) level or at various micro levels, such as a sector of the economy, an industry, an individual company or an individual project.

Unfortunately, there is currently an important difference of opinion among prominent economists as to the <u>proper method of measuring productivity</u>, and hence the impact of R&D on the domestic economy. The central issue of this controversy, as seen from an applied point of view, is whether productivity can be measured at the national (macro) level with any degree of confidence. This controversy can be seen in the positions of two schools of thought who hold widely divergent opinions on the importance of productivity in the American economy. It is this wide difference of opinions that leads many to doubt the <u>credibility</u> of national productivity estimates. A consequence of this inability to measure seems to be a vacillation in the formulation of forthright strong federal R&D (or technology) goals and initiatives throughout the 1970s. This inability of economists to agree on proper measures is confused by them as well as policymakers, with a persistent doubt as to the efficacy of R&D in economic systems and its overriding importance to the long term position of the United States*.

*Heiss, Knorr, Morgenstern, <u>Long Term Projections of Power</u>, 1973.

The first position, presented by the bulk of the literature published in this field, holds that increases in productivity have been a significant factor behind the post war boom economy. The notable advocates for this school, Dennison and Kendrick, though they admit the accuracy of the national data used in their calculations is suspect, contend that these difficulties can be corrected. Jorgenson and Griliches, members of the opposition, have found that post war growth in the national output was almost all due to increases in the labor force and capital expenditures and, as a result, productivity gains were nearly insignificant. Though Jorgenson and Griliches have also admitted that national data are often inaccurate, importantly they contend that Dennison et. al. were guilty of severe errors in aggregating the national accounts, i.e., mixing apples and oranges.

We believe that the essential difference between the two schools lies not in the data used nor in the quality of scholarship but rather in aggregation techniques used. These slight differences in calculation extend to the many other empirical studies that have attempted to find the national rate of productivity growth. As a result, almost any economist who attempts to link R&D to a national productivity estimate could vastly alter the final results by using the various productivity time series currently available, even if the choice were narrowed to one school of thought. As to the political nature of this controversy it appears that the Department of Commerce and other federal agencies find it necessary to publish <u>some</u> estimate of productivity though their results may be doubtful. Furthermore, it appears that the Dennison-Kendrick position has gained wider acceptance since the concept of significant productivity growth is more pleasing than the absence of such growth.

In part due to doubts over the national productivity estimates, some economists have approached the measurement of productivity and the impact of R&D by individual sectors of the economy. The thinking is that the detailed nature of such studies would remove at least some of the errors involved in the national aggregation. To accomplish this task for every sector in the economy would be very expensive. Moreover there exist complex interrelationships between sectors that would be almost impossible to account for without using national data. It appears, therefore, that given the current abilities of economists, estimation of a credible national productivity estimate--that would be universally acceptable--is impossible.

The question is not simply whether one desires a knowledge of the impact of R&D spending at the national, sector, industry or project level, but rather which level of analysis is more credible for a given purpose. As a result of these concerns some economists have studied the impact of R&D at the sector, industry, or project levels. When data are available and the problem of sector aggregation is minimal such studies are considered to be generally credible. The state of the art in this technique is fairly well developed, both in the public and private sectors. One such example is presented by ECON's telecommunications econometric model, specifically designed to measure the impact of R&D expenditures on this sector of industry. Large corporations and industry associations have frequently studied R&D performance at these levels in similar ways. In both government and industry, project by project benefit cost analyses of R&D are common. One of the foremost researchers in this field is Edwin Mansfield (Edwin Mansfield, Industrial Research and Technological Innovation, Norton and Company, New York, 1968). We must point out though, that there are serious difficulties even at this level but we believe these problems are mostly study specific and that methodology used to examine the impact of R&D expenditures at the sector, industry or project level is generally acceptable within the economic community.

The findings at the sector, industry or project level generally are strong, and attribute anywhere from 20 to 50 percent of increased output levels to the effect of R&D and technology. A note of caution however is advisable: typically ventures known export to have been particularly successful are selected for study of such ventures. Not studied to equal detail and enthusiasms are the many failures along the road of successful R&D, technology and innovation. Yet, the general finding of a strong sector specific impact of R&D is generally more accepted in the economic community than any proven impact at the national, or macro, level.

2.0 The International Trade Impact of R&D and Technology.

Given the contradictory and unsatisfactory findings of economic research to date on the role of R&D--and of federally financed R&D on the national economy--ECON is currently investigating what we believe to be one of the strongest empirical cases to be made for an active federal and national policy on R&D, and the process of innovation: the impact R&D and resulting technology have on the competitive position of the United States in world trade.

Given the long history of economic thought--expressed foremost by the great Austrian economist Joseph A. Schumpeter--concerning the advantageous position of innovative economics and enterprises due to their degree of technological advantage, it is astonsihing to find how little empirical research has been done in tying R&D and innovation to the international trade position of the United States.

In the literature one may well distinguish between two broad theories of the impact of R&D on the trade position of countries: the technology gap trade theories and the product life cycle trade theories. The first group of papers and publications directly attribute trade flows to technology gaps between countries. Foremost among exponents of this theory are Posner (1961), Posner and Hufbauer (1966) and since then many others. Underlying many of these investigations is, of course, the work by Schumpeter on innovation, enterprise and economic systems.

The product life cycle trade theories emphasize the market aspects of new products, the initial advantage enjoyed by the new product company or country, after a varying period of initial advantage, other companies and countries will catch up with imitative products of their own in the same field to gradually erode that advantage. Typical product life cycle advantages last from seven to fifteen years.

I for one am not sure whether the two theories are necessarily exclusive of each other, quite to the contrary. However, the second set of theories would emphasize the product and image aspects of marketing, rather than the essentially innovative functions of R&D. To the extent that these latter also are important this increases somewhat the difficulties of tracing R&D, and innovation to the international trade position of the United States. The foremost exponent of the product life cycle trade theory are Hirsch (1967) based on work by Dean (1950), Linder ("preference similarity" trade theories), Vernon (1966), Wells (1966) and Walker (1977).

The current research by ECON tries to extend and improve upon work which was first presented in the Journal of Political Economy in February, 1967: in the first section of a study by William Gruber, Dileep Mehta, and Raymond Vernon, the authors investigated the impact of R&D expenditures on the trade balance of the U.S. In particular, their hypothesis was that those industries in the U.S. economy which were characterized by an intensive R&D effort were also the industries that performed well in terms of their export balance. This is the very subject of today's hearings before these two committees of the Senate.

The basis of this belief of advantage can either be attributed to the technology gap or the product life cycle theories of international trade: firms can compete with each other by introducing new or differentiated products, which then enjoy transient monopoly status by virtue or the time which would be necessary in order to duplicate the research efforts which led to their introduction. In addition, one can argue that a similar kind of transient of market power would accrue to any firm that put its efforts into process innovation with the objective of lowering costs for an existing product. There are "rents" (unique advantages) to be had during the time which it takes competitors to duplicate innovations (see Schumpeter's explanation of profits in competitive market systems).

ECON is currently trying to update and improve on the work by Gruber et. al. in a couple of ways: firstly, we want to make another sampling at a more recent date so as to reverify the original findings and to check that the relationship which was presented for 1962 is currently affecting the U.S. trade balance. Secondly, we are trying to improve on the measures of export intensity and R&D effort. If one takes the results by Gruber et. al. at their face value there are two possible interpretations. One might suggest that the current level of R&D effort affects the current trade posture. This tends to contradict the hypothesis that Gruber et. al. are attempting to establish, namely that the lags between expenditure of research resources and the appearance of new products is the source of the superior market position in newly developed products. On the contrary, one might interpret their tests as a corroboration of the existence of an ongoing or steady state link between research effort and the trade balance. With this interpretation one must still fault the test presented by Gruber et. al. in that the data for any particular year should contain a large component of "noise" obscuring the long run relationship.

A fair summary of the preliminary results are shown in Table 1 and Figures 1 and 2. The average R&D efforts and trade performance by 15 SIC Level II product groups over the time period 1958 to 1975 are shown in Table 1. By far the strongest performers with regard to R&D and export share of sales are aircraft industry and (none electrical) machinery (which includes computers). The net trade position of R&D intensive industries is dominated by aerospace, when compared to non R&D intensive industries. In Figure 1 we show the relative (percentage of sales) trade intensity of 15 specific United States industries (exports and net trade) while on the vertical axis we show the research intensity of that same industry (again R&D expenditures as a percentage of total sales). Whether expressed in terms of exports over sales or net trade (exports minus imports for Level II SIC code commodity groups) we find that by 1975 the significant contributors to the balance of trade are nearly exclusively research and development intensive industries, while industries with little research and development funding, make hardly any contribution to U.S. exports and show a substantial import deficit. These results are so strong, statistically, that indeed this finding must be considered a strong confirmation of the school of economic thought that has tried--or claimed-- to establish strong empirical relations between R&D and the national economy. If one included in this listing agricultural trade--another R&D and technology intensive sector of the U.S. economy--the results would even be stronger.

We are currently extending our investigation to tracing federal funding of R&D to these same product groups in international trade. Preliminary

TABLE 1 AVERAGE R&D EFFORT AND TRADE PERFORMANCE, 1958-1975

	R&D SALES	SCIENCE AND ENGINEERING EMPLOYMENT	EXPORT SALES	EXPORT-IMPORT SALES
TRANSPORTATION(37)	8.60	6.14	7.16	2.16
AIRCRAFT (372)	24.18	12.92	11.45	10.13
NON-AIRCRAFT (37_)	2.66	2.16	5.60	-0.77
ELECTRICAL MACHINERY (36)	7.44	4.98	4.48	1.37
INSTRUMENTS (38)	4.83	3.11	9.14	4.98
CHEMICALS (28)	3.23	4.09	6.98	4.99
DRUGS (283)	4.29	6.62	5.63	4.15
NON-DRUGS (28_)	3.03	3.68	7.35	5.24
MACHINERY (NON-ELECTRICAL) (35)	2.94	2.00	12.92	2.77
RUBBER AND PLASTIC (30)	1.30	1.17	2.79	0.17
STONE, CLAY, GLASS (32)	0.87	0.60	2.43	-0.39
PETROLEUM AND COAL (29)	0.80	4.53	1.18	-1.71
FABRICATED METAL (34)	0.65	0.56	3.77	2.01
PAPER (26)	0.65	0.58	4.40	-3.67
PRIMARY METALS (33)	0.56	0.47	3.59	-3.79
NON-FERROUS (333)	0.67	0.62	3.96	-5.45
FERROUS (33_)	0.48	0.40	3.38	-2.91
FOOD (20)	0.20	0.34	2.79	0.61

Figure 1: Gross Exports vs. R&D for 15 Industrial Sectors
(Level 2 SIC codes, Percentage of Sales)
1975

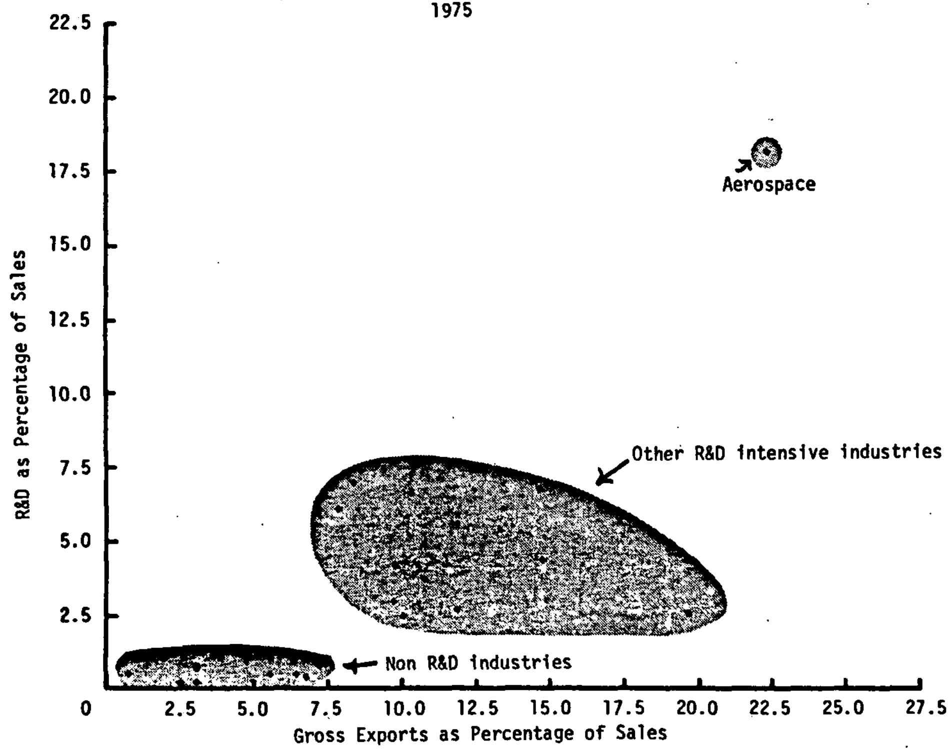
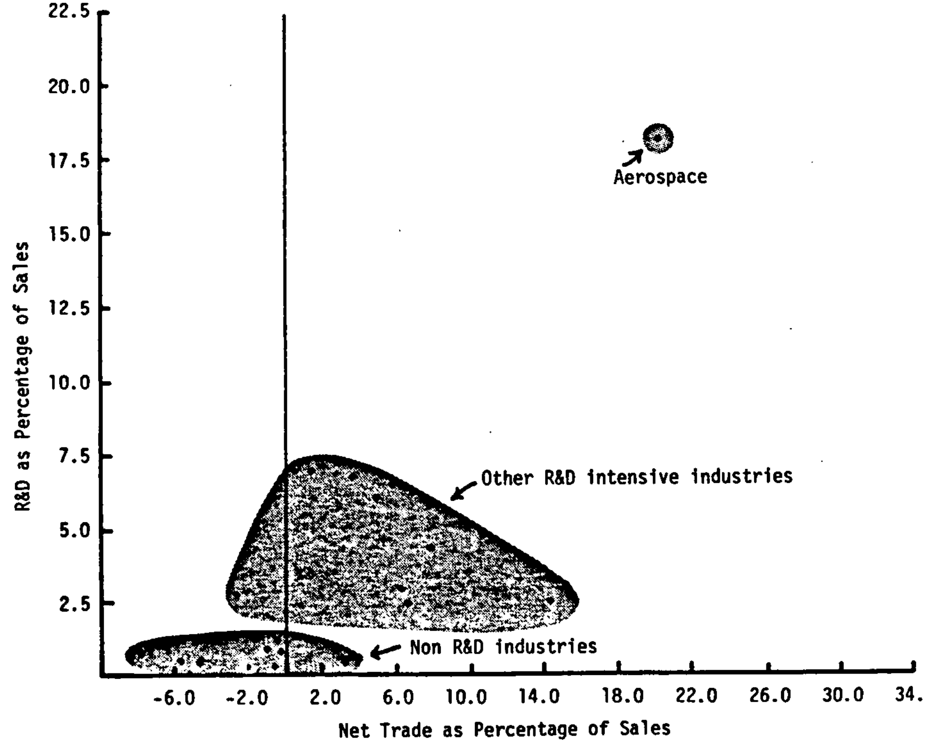


Figure 2: Net Trade vs. R&D for 15 Industrial Sectors.
(Level 2 SIC codes, Percentage of Sales)
1975



results indicate that the relationships between federal R&D and the competitive world position of the United States is even stronger than the statistical correlations found between total R&D and these same product groups.

Given the strong link between R&D and the international trade position of the United States the formulation of an active, forward looking R&D policy--particularly of applied R&D and its demonstration--by the federal government as well as industry must be regarded as one of the cornerstones to preserving the future international trade position of the United States. Such an active R&D policy would be an expression of substantive economic policy, rather than policies that concentrate on monetary and fiscal stop gaps. This process is not one of immediate results and success, but is required and has to be pursued with persistence over the next decades.

3.0 Needed: A turn-around in federal funding of R&D. Much has been said about the role, or non-role, of the federal government in the pursuit and/or financing of R&D, including industrial R&D. The special analysis of the Office of Management and Budget of Fiscal Year 1979 of federal funding of R&D in the United States paints an overly optimistic and rosey picture of what has or has not been done in this area by the federal government*. All too hastily the analysis claims that R&D funding has been increased and turned around. This, however, is just not the case. Table 2 and Figure 3 show that in constant dollars (second quarter 1972 dollars) total dollar

*Office of Management and Budget, Special Analyses--Budget of the United States Government, Section P--Research and Development, GPO, 1978.

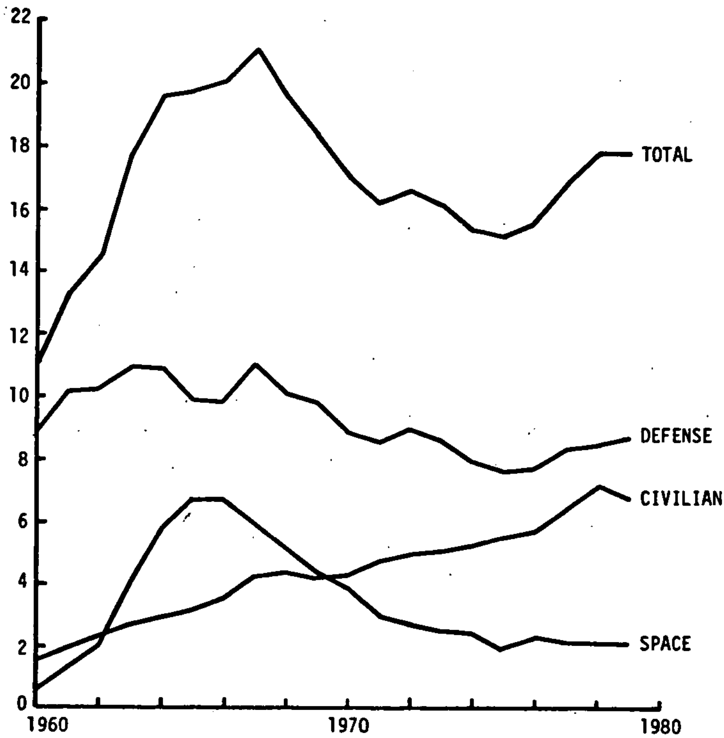
Table 2

TRENDS IN CONDUCT OF R & D BY MAJOR PROGRAM AREA: 1960-1979
(obligations in billions of dollars)

(constant 2nd Quarter 1972 dollars)

Year	Defense	Civilian (other than space)	Space	Total	Percent of GNP
1960-1964	50.9	11.4	13.8	76.1	1.89
1965-1969	50.6	19.3	28.7	98.6	1.94
1970-1974	42.7	24.1	14.3	81.1	1.39
1975-1979	40.9	31.4	10.5	82.9	1.24

Figure 3:
2ND QUARTER IMPLCIT GNP PRICE DEFLATER SERIES
TRENDS IN CONDUCT OF FEDERAL R&D BY MAJOR PROGRAM
CONSTANT 1972 DOLLARS*
(2nd QUARTER)



*Using 2nd quarter implicit GNP price deflater series, assumed information 1978: 6 percent, 1979: 6 percent.

funding of R&D has decreased by 25 percent in the 1970s when compared to the 1965-1969 period. Defense funding for the decade of the 1970s has decreased by $20 billion ($10 billion in each 5 year period), i.e., 25 percent when compared to the 1960s. The space R&D effort (accepting OMBs definition) has decreased twofold when compared to the late 60s. The only positive development in this table is the three fold expansion of civilian R&D, from $11 billion to $31 billion.

The surprising fact from these figures is that the area where some of the answers would seem to come most difficult to the federal government, namely the funding of civilian R&D, the performance by the federal government over the past twenty years has been in the right direction.

It is in the two areas where one would think a strong national leadership by the federal government would come easiest (in defense and space), where an absolute dollar funding cutback of major proportions has occurred in the 70s, and this trend has not been reversed in fiscal year 1979. The question is whether this continued stagnation--and continued cutback when compared to the 1960s--is a deliberately considered federal policy, or whether this is simply an accidental, inadvertent happening due to "money illusion" a term used by economists to describe the perceived--but illusory--income increases at level of 2 to 3 percent inflation.

Misdirected as this overall trend of relative emphasis is, the message becomes more alarming when seen in terms of Table 3 where the relative

Table 3

TRENDS IN CONDUCT OF R & D BY MAJOR PROGRAM AREA: 1977-1979
(obligations in billions of dollars)

(as precent of GNP)

Year	Defense	Civilian	Space	Total
1960-4	1.27	.28	.34	1.89
1965-9	1.00	.38	.56	1.94
1970-4	.73	.41	.25	1.39
1975-9	.62	.47	.15	1.24

emphasis given to R&D in the economic system is shown--as a percentage of GNP. Defense and space R&D activities have both been cut dramatically, defense by over 50 percent (1.27 percent to .62 percent) and space by over 70 percent (from a high of .56 percent to .15 percent). While some may consider this cutback of defense and space related R&D as not too worrisome, it is nevertheless the R&D performed by industry in these specific areas which has led to the most dramatic and strongest trade positions of the United States over the past 20 years: Aerospace, R&D and its many spinoffs to other economic sectors, computer technology, cryogenic multi layer insulation, gas turbins, integrated circuits, communications technology, etc.

4.0 The Concept of R&D Venture Corporations. Under point 5 of your letter of invitation you raise the issue of "How can R&D investments be increased and directed towards improving the U.S. trade position in high technology fields?" my single answer if limited to one, is to make up and turn around a nearly $15 billion R&D funding gap (FY 1979 dollars) that, by accident or design, developed in the 1970s.

Another suggestion is to be somewhat innovative in institutional, fiscal and other matters with regard to fostering investments in new R&D by private, industrial sectors of the U.S. economy. I specifically suggest that ventures performed therein in the pursuit of R&D be allowed a multiple write-off for the initial investment. Such schemes are currently in use in European countries (Germany). They are not schemes of subsidization, but rather recognize the non-zero sum character of innovation: if investments in innovation are made and pay off, they are a net addition to the wealth of a nation, rather than side payments from one pocket into others. Hence, given tax incentives in the form of multiple depreciations of the initial investments (e.g., three fold) only means that the government's 48 percent share of gains from such innovations are deferred by possibly one or two years, if and only if the venture is successful. In case of unsuccessful ventures it is still the investors, loss, as it should be.

This innovative institutional arrangement for R&D ventures--which would have to be approved beforehand by the government to qualify for such tax regulation--has led among others in Germany to the development of space transportation ventures (OTRAG), ventures which in the United States under tax laws and economic thinking today are simply not possible. This higher degree of economic sophistication in economic matters is a greatly needed ingredient to assure a future strong role of the United States in international markets.

5.0 Conclusions. These matters are extremely serious: while currently a widespread school of economic thought in the United States takes pleasure in recurring to devaluations of the dollar to solve international balance of paymetns problems, may I point out that the United States has a tremendous stake in the international monetary system to be safeguarded. As of today hundreds of billions of paper dollars are held by foreign institutions, private investors and governments, the dollar still being the foremost international means of exchange and reserve. The benefits the United States derives from these dollar paper and accounting holdings aboard surpass in magnitude many fold any benefits other nations derive from foreign aid programs the United States is financing today. Rather than a giver of foreign aid the United States has been a massive recipient of foreign aid throughout the 1970s in the form of these persistent, massive balance of payments deficits. It is this aspect that I believe is somewhat overlooked too quickly when discussing the seriousness of the need for a stable dollar in world currency markets. This stability can only be maintained with a substantive domestic and foreign economic policy by the United States. Part of that substance has to be an innovative aggressive forward looking R&D policy by the federal government, as well as industry. On the federal side the turnaround in the substantial decreases of federal funding of R&D has to be achieved. On the private side, some innovative institutional approaches are necessary to maintain and increase the rate of innovation. This might be accomplished by allowing R&D ventures to write off multiples of their original investment before being subject to federal income taxation. This approach seems to be successful in Europe, and it is time the United States took similar initiatives.

Thank you very much for the opportunity to present these views of your committees.

Senator STEVENSON. Thank you, sir. Do your statistics include comparative figures on R. & D. for other countries?

Dr. HEISS. No. We only studied the United States and their exports. OECD is currently undertaking a major comparative study. I believe the University of Sussex is one of their lead centers for that investigation. But I believe their results will not be available soon. It is tremendously complicated to make international comparisons, it is difficult enough to study the U.S. data, let alone to truly study international comparative data. The OECD is undertaking a major exercise there. Its findings show the same results for the United States; their preliminary findings are identical to what I just said.

Senator STEVENSON. Dr. Steele.

[The prepared statement of Dr. Lowell W. Steele follows:]

STATEMENT OF
DR. LOWELL W. STEELE
MANAGER OF RESEARCH AND DEVELOPMENT PLANNING
CORPORATE RESEARCH AND DEVELOPMENT
THE GENERAL ELECTRIC COMPANY

BEFORE THE
JOINT HEARINGS OF
THE SUBCOMMITTEE ON INTERNATIONAL FINANCE
OF THE COMMITTEE ON BANKING, HOUSING AND URBAN AFFAIRS
AND
THE SUBCOMMITTEE ON SCIENCE, TECHNOLOGY AND SPACE
OF THE
COMMITTEE ON COMMERCE, SCIENCE AND TRANSPORTATION
MAY 16, 1978

Mr. Chairman and Members of the Subcommittees.

My name is Lowell Steele. I'm Manager of Research and Development Planning for Corporate Research and Development in the General Electric Company. I appreciate this opportunity to appear before you today to address some of the questions you have raised regarding the relationship between investment in research and development, U.S. technological leadership, and our position in international trade. Needless to say, the questions you have raised are exceedingly complex and there are no definitive answers. If that were not the case, there would be no need for this hearing. One of the serious impediments to better understanding and more effective policies in this area is the scarcity of reliable, relevant information. In many cases, one is forced to draw inferences from indirect evidence, to make judgments based on exceedingly limited data and, often, we are reduced to relying on judgment based on experience.

I'm delighted that this committee has chosen to focus on the broad effects of Federal policy on U.S. technological competitiveness. As you will see from my comments, I believe it is important to address the questions you have raised in the context of these more general policy considerations. Our goal is to achieve the economic vitality and competitiveness which flows from the entire innovation process, that is to say, the process of conversion of scientific advance to commercial application. Effective action may well be in improvement of more general areas of economic and other Federal policies affecting the investment climate rather than direct measures to stimulate R&D alone. We need to include in our purview all of those elements that affect the efficiency and magnitude of U.S. innovative effort, not just the R&D portion.

My comments this morning will be divided into five parts. First, I will examine some of the evidence relating R&D, economic performance and international competitiveness. Second, I will review the trends in the domestic situation with respect to industrial research and development, productivity and output growth, and capacity to invest. Third, Federal policies that affect innovation and economic growth will be discussed. Fourth, I will consider some of the concerns and issues that are related to international technology transfer. And, finally, I will suggest some policy changes that could lead to improvements.

* * * * * *

R&D, ECONOMIC PERFORMANCE, AND INTERNATIONAL COMPETITIVENESS

In the most general sense, success in foreign trade is governed by the principles controlling any form of trade - in order to succeed one needs some form of competitive advantage. It is unlikely that one can be successful internationally in an industrial sector in which one is weak or inefficient domestically.

Consequently, we can get some insight into the question of the relation between R&D and exports if we begin by looking at economic performance of various sectors of industry for the major industrial countries. Table I presents such data (taken from a draft report of the NSF). R&D intensity[*] of an industrial sector is expressed as a percentage of value added; i.e., the value of the productive services used to produce a given output. Within each country, it appears that higher levels of R&D are generally associated with higher growth in labor productivity and industrial production. It is noteworthy that the average export growth ratio for the R&D-intense sectors was higher than other OECD manufactures exports between 1968 and 1976 - 4.17 compared to 3.83.

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[*] Only enterprise-funded R&D is used since recent economic studies have failed to trace any growth in productivity to government-funded R&D.

Table I

R&D AND GROWTH OF PRODUCTIVITY AND INDUSTRIAL PRODUCTION
AMONG TECHNOLOGY INTENSIVE INDUSTRY GROUPS

	U.S.			France			FRG			Japan			U.K.		
	(a) R&D	(b) Productivity	(c) Output	(a) R&D	(b) Productivity	(c) Output	(a) R&D	(b) Productivity	(c) Output	(a) R&D	(b) Productivity	(c) Output	(a) R&D	(b) Productivity	(c) Output
Electrical Machinery	7.2	5.9	6.1	7.7	6.7	10.6	7.9	6.6	10.2	7.1	13.3	18.5	5.4	5.3	4.7
Chemicals	4.9	6.7	6.5	5.2	8.5	10.4	7.8	5.5	9.6	6.1	12.6	13.6	5.4	5.2	5.9
Nonelectrical Machinery and Instruments	4.2	3.5	2.8	1.7	5.2	7.7	na	2.3	4.5	2.1	8.4	14.1	1.7	3.1	1.4
Total Manufacturing	3.0	2.7	4.5	1.7	6.0	6.4	2.6	5.9	5.8	2.7	10.7	12.5	2.0	4.4	3.6
Metals	1.0	1.1	1.8	0.7	3.6	4.6	0.8	4.4	6.1	1.6	9.6	12.4	0.9	-0.3	0.7

(a) R&D = Enterprise Funded R&D as % of Value Added, Average 1963-1973
(b) Productivity = Labor Productivity Growth (%), Average 1968-1973
(c) Output = Industrial Production Growth (%), Average 1967-1973

NOTE: These five countries perform about 95% of the world's R&D, and these research-intense industry sectors - machinery and chemicals - perform 50% to 75% of their nation's enterprise-funded R&D. Also, exports of these five nations accounted for 70% of the world's export market in machinery and chemicals in 1976.

Another examination of international trade in technology-intensive products has been made by the Office of Economic Research in the Department of Commerce. Using a more rigorous definition of technological intensity than had been used heretofore, that study shows

- a growing percentage of high-technology products in our manufactures exports -- 42.5% in 1974 compared with 40.5% in 1968;

- faster growth of U.S. technology-intensive exports relative to non-technology-intensive -- 10.7% annual average between 1968 and 1974 compared with 9.2%, and

- a generally increasing U.S. positive trade balance for the technology-intensive products group -- $5.7 billion in 1968 compared with $13.8 billion in 1977 -- compared with a negative balance for nontechnology-intensive products.

These findings generally lead to the conclusion that technologically intense products do better than average in international trade, but they do not provide a direct answer to the technological leadership question. A more direct approach might be to look at trends in the international competitiveness of our products in terms of trends in our share of OECD export markets.

From a businessman's point of view, the best single measure of competitive performance and the most reliable indicator of future business success is the market share trend. The previously mentioned Commerce Department study found a U.S. share decrease from 28% to 23% between 1968 and 1974 for technology-intensive products. And Table II shows that our 1976 share levels in the R&D intensive industry sectors are well below those of 1968.

Table II

U.S. Market Share for R&D Intensive Industry Sectors (%)

	1968	1976
Chemicals	22	17
Electrical Machinery	22	19
Nonelectrical Machinery	27	24
Total Manufacturing	20	16

So, regardless of who has the lead in technology, the long-term trends in competitiveness of U.S. products in world markets are not what we would like.

Since it appears that more R&D intense products do better in overall trade balance and growth of exports, one might be led to the conclusion that if we simply increase our R&D levels, we could grow our exports even more rapidly. But the argument might well be made that R&D intensity is simply a concomitant of growing markets and high exports -- that these industries do more R&D because they are more successful in both domestic and international markets and have higher profit levels to plow back into R&D. Or, it might be claimed that the better performance is coming from relatively more sophisticated managements and work forces --or from higher levels of investment in more modern plants and equipment which permits higher quality, lower priced products.

I am convinced that all these statements are true. Companies do more R&D when the competitive environment supports it, the industrial infrastructure facilitates it, the profit opportunity motivates it, and when they can afford to invest more. It is important to keep in mind that R&D is an investment - a relatively, risky, long-term investment. Unless there is a reasonable prospect of a future return commensurate with the risk, the investment will - quite properly, in economic terms - be regarded as unattractive. Businessmen do not stop investments in R&D because they lose their nerve, but because they see alternative investment opportunities that appear more attractive.

We all too frequently forget the fact that many - probably most - attempts at innovation fail. When they do, people get hurt. They lose their jobs, they lose their savings, stockholders see their equity eroded or destroyed. Unless the calculable potential return is significant, innovation will not flourish.

And, of course, investment in R&D is only a first small step in the innovation process. Before new products or processes can be exploited, it normally is necessary to make much larger commitments to facilities and machines, train employees in new skills, and so on. Thus, without the availability of money to create both knowledge and tangible capital, businesses simply cannot enter into the innovative process.

Maintenance of technological leadership in an industry may not depend so much on the conduct of a relatively high level of in-house R&D as on a balanced investment program in application of advances from all areas. And balanced business investment depends on the financial ability and economic incentives for an industry to invest in the future -- to take advantage of available advances in technology to modernize its plants and tools and machines needed to improve its productivity and product quality -- to invest in the longer-term future.

Dr. Bela Gold's recent testimony before this committee painted the sad picture of how we have lost our technological lead in steelmaking to the Japanese. While we were "jawboning" the U.S. steel industry to hold down its prices to "control" inflation, the Japanese were making the investments needed to revolutionize their steel industry. Now the world's technological leader in steelmaking, Japan can be expected to dominate the world steel export market through 1990. U.S. Steel Corporation reports that breakeven price for major U.S. producers is 128% of

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Japanese producers. Our steel labor costs per ton are 86% higher than for Japan, and it has been estimated that our 1976 steel imports cost us 100,000 steelmaking jobs.

The steel industry story helps to demonstrate the importance of longer-term investment in both knowledge capital and tangible capital in order to provide the technological innovation that increases productivity and keeps an industry competitive. The value of separating out the so-called technology intensive products for analysis should not be misinterpreted. While this allows us to compare performance of businesses as a function of R&D intensity, we must not overlook the fact that technology development and innovation can be critical to any business if its innovation investment levels allow it to fall behind its competition. The key factor in maintaining a viable business is to be able to anticipate accurately and respond to market forces in a timely manner and to make the necessary investments to keep up and occasionally lead the competition.

Some of the characteristics of businesses with high R&D intensity are that markets typically are growing and products are changing more rapidly than is true of most businesses. High R&D is simply essential to staying in the business. As a given business or product line becomes more mature, R&D intensity may decline, but there is still a need for process R&D and investment in innovation -- to allow for continuing quality and price improvement. When businesses reach these later stages of maturity, products become more commodity-like and price becomes a much more dominant factor in determining which firm captures the market. These mature businesses are thus much more sensitive to fluctuating economic conditions. This helps to explain why we have seen a stronger and more stable performance in international trade by our high-technology businesses. But it also demonstrates why we must concentrate on providing the economic environment in which incentives and ability for continued investment in innovation are adequate to sustain international competitiveness across the board.

While performance of our high-technology products in international trade has been good, there are signals that cause concern for the future competitiveness of all U.S. manufactured products. And we must not forget that the U.S. domestic market is increasingly subject to international competition. As you know, there is a strong trend toward foreign investment in U.S.-based production and marketing capacity. Also, the heavy growth of patenting activity by foreign residents is a precursor to increased foreign entry in U.S. domestic markets.

So what are some of these signals that cause concern for the future? Specifically, they are

- trends in industrial investment in R&D
- trends in tangible capital investment, productivity and output growth
- trends in industry capacity to invest
- trends in Federal policies affecting innovation.

TRENDS IN R&D EFFORT

Two issues are important in considering current trends in industrial R&D. First: Is the level of R&D effort adequate to sustain technologically strong and internationally competitive industries? Second: Is effort in innovative, longer-term, growth-oriented projects balanced properly with defensive, evolutionary technological improvement and regulatory compliance activities?

As you know, U.S. enterprise-funded R&D effort has been gradually increasing in terms of constant dollars, but it is not quite keeping up with the growth of GNP (Table III).

Table III

U.S. Enterprise-Funded R&D

	Constant 1972 Dollars ($ Billions)	Percent of GNP
1970	11.4	1.06
1975	12.1	0.98
1978	12.7(est.)	0.91

And if we look at U.S. effort in comparison with our two major international competitors, Japan and Germany, we find cause for concern. Comparing on the basis of total national R&D expenditures that are aimed at economic development and advancement of knowledge, we estimate the U.S. effort in 1976 was 1.13% of GNP compared with 1.63% for the FRG and 1.80% for Japan. The discrepancy between these figures and those commonly seen is explained by the fact that almost half of the U.S. effort is spent on defense, space and socially-oriented activities while virtually all of Japan's and about three-quarters of German R&D are aimed at economic development and advancement of knowledge.

More important to maintaining technological leadership is the fact that our longer-term R&D appears to be suffering more than the near term. R&D managers report a heavy shift in emphasis to shorter-term, defensive projects aimed at incremental or evolutionary change and regulatory compliance. One major chemical company recently reported that 20% of its 1976 R&D budget was to meet Federal regulatory demands.

Further evidence of the shift toward shorter-term emphasis in industry R&D is the declining support of basic research. According to NSF data, constant dollar funding by industry fell by 21% between 1966 and 1976. This decrease was accompanied by a drop of 77% in Federal support for basic research in industry.

While we can only speculate as to the effects of this reduction in longer-term, high-risk investment, we do know that some of the most striking and useful innovations often arise from basic work. In one area - solid state physics - shares of four Nobel Prizes have been awarded to industrial scientists. It is no coincidence that the fruits of this science have led to U.S. dominance in solid state technology. The transistor, the superconducting magnet, the electroluminescent display, the new magnet materials, the large-scale integrated circuit and all the rest of a multi-billion dollar industry stand as testimony to the effectiveness of that enterprise.

Although, according to NSF, industry performed more basic research than the universities in the 1950s, the universities now do more than three times the amount of basic research done by industry. There is thus the possibility that we shall move into an age of two or more scientific cultures, university science and the others. To a large extent this division occurs in Great Britain. The gap may be a significant factor in their inability to bring scientific advances to the marketplace.

TRENDS IN INVESTMENT, PRODUCTIVITY AND OUTPUT GROWTH

As I stated earlier, maintenance of a viable and competitive business requires a balanced investment program in both R&D and tangible capital. So our lagging investment in R&D is only part of the story.

A study by the U.S. Treasury covering the period 1960-1973 shows the U.S. lagging other nations in investment, economic growth, and productivity growth (Table IV).

Table IV

	Investment Ratio		Output Growth Rate		Productivity Growth	
	Percent of GNP	Rank	Percent	Rank	Percent	Rank
Japan	29.0	1	10.8	1	10.5	1
West Germany	20.0	2	5.5	3	5.8	3
France	18.2	3	5.9	2	6.0	2
U.K.	15.2	4	2.9	5	4.0	4
U.S.	13.6	5	4.1	4	3.3	5

It is not surprising then to find that our performance in the export of manufactured goods has not kept pace with competition. The following table (Table V) shows that between 1968 and 1976, the growth of exports for each country is in rather close correspondence with its relative performance in terms of investment, output and productivity growth shown in the preceding table (Table IV). Growth of U.S. and U.K. exports was far below that of the other major competitors, and the U.S. lost its position as the world's leading exporter of manufactured products. It is painful to note that had we maintained our share of the manufactures export market we would have realized an additional $17 billion in exports in 1976. Furthermore, based on the estimate that each $1 billion of exports creates 40,000 U.S. jobs, we would have been able to employ an additional 680,000 Americans.

Table V

Exports of Manufacturers

	1968		1976			
	$B	% Market Share	$B	% Market Share	Growth Ratio	Rank
Japan	12.2	10.1	64.6	13.5	5.30	1
FRG	22.3	18.5	90.7	18.9	4.07	3
France	9.4	7.8	43.0	9.0	4.57	2
U.K.	12.7	10.5	38.3	8.0	3.02	5
U.S.	23.8	20.0	77.2	16.1	3.27	4

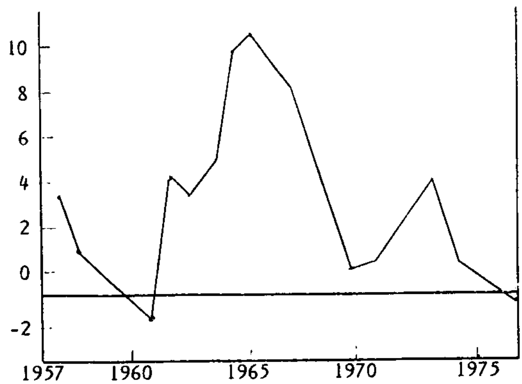
Currently, the Council of Economic Advisors says a 10% per year increase is needed over the next several years to achieve our national goals in terms of jobs, economic growth, and a balanced Federal budget. However, the Commerce Department forecasts only a 5.5% increase in 1978.

TRENDS IN INDUSTRY CAPACITY TO INVEST

Our lack of growth of investment may appear puzzling when one reads in the papers about how industry profits have been increasing rapidly. But if we look at the investment record in comparison with effective returns on equity capital as displayed by Figure 1, we see a striking correspondence. The shape of the investment curve at the top follows very closely the shape of the earnings curve at the bottom of the figure.

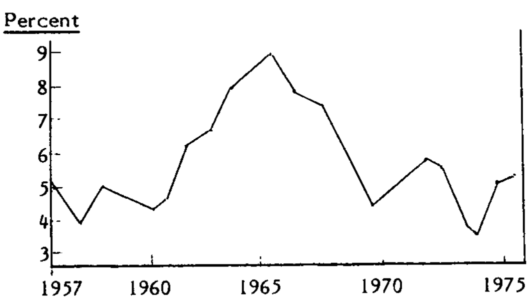
Figure 1

GROWTH IN REAL BUSINESS FIXED INVESTMENT
(Rolling 4-Year Average)



Source: Department of Commerce

AFTER TAX RETURN ON EQUITY CAPITAL



Source: Burton Malkiel; FORTUNE (11/77)

After-tax Returns on Equity Capital represent the sum of after-tax profits (adjusted for underdepreciation and inventory gains) plus the reduction of the real value of debt due to inflation expressed as a percent of capital stock valued at replacement cost. Data pertain to nonfinancial corporations, not cyclically adjusted.

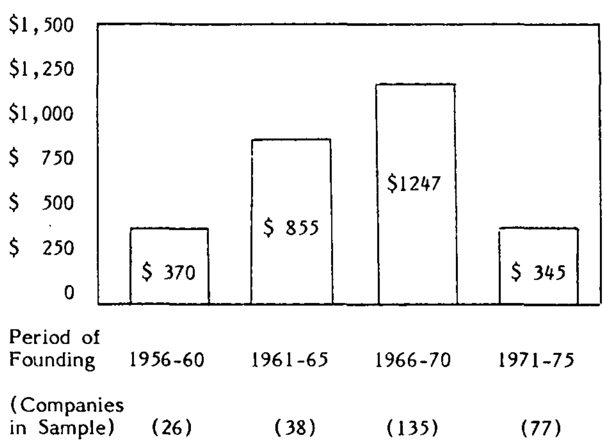
Of course externally generated funds also are extremely important in considering trends in industry capacity to invest in R&D and innovation. Their importance is magnified by the fact that they are often the only source of capital for starting or expanding the smaller, more innovative firms.

The New York Stock Exchange reports that risk capital has been going down by $6 billion per year, and Figure 2 shows data reported from a member survey by the American Electronics Association. Reflecting the drop in risk capital availability, the 1971-1975 period was the poorest of the prior 20 years.

Figure 2

Average Capital Raised By Companies Founded in the Period
($000's)

(Constant 1972 Dollars)



We also know that the number of successful public issues for small technical companies fell from 200 to none between 1969 and 1975.

Table VI, also from the American Electronics Association survey, demonstrates why risk capital is so important.

Table VI

BENEFITS IN 1976 PER $100 INVESTED

Years Founded	Companies in Sample	Foreign Sales	R&D Expense	Federal Corporate Tax	State & Local Tax	Personal Income Tax	Total Fed. Tax Revenue
1956-60	26	$91	$19	$ 7	$3	$12	$19
1961-65	38	89	18	9	5	13	22
1966-70	135	57	20	12	4	11	23
1971-75	77	70	33	15	5	15	30
1956-75	276	$76	$20	$10	$4	$12	$22

Take, for example, the 77 companies founded most recently in the 1971-75 time period. Benefits for each $100 invested in those - on average - four year old companies in 1976 were,

$70 in export sales

$33 spent on R&D

$15 paid in Federal corporate taxes

$5 in state and local taxes, and

$15 in personal Federal taxes through jobs created.

TRENDS IN FEDERAL POLICIES AFFECTING INNOVATION

The focus of these hearings is on the complex of relationships between technological leadership and foreign trade. As you can probably infer from my earlier comments, I believe the most fruitful way to approach these subjects is to focus first on the domestic situation, because a vital, growing, effective domestic economy is the cornerstone of foreign trade. Furthermore, the ability of our economy to maintain a high level of innovative activity is critical to its vitality and growth. Federal policies have a powerful effect on the capacity and the propensity to innovate in two principal areas -- the perception of future risk or uncertainty compared with the potential return and the availability of resources to invest in the future.

All technological innovations face the uncertainty of whether or not cost competitive technological feasibility can be demonstrated. If the innovation is aimed at a new or improved product, there is the additional uncertainty of market acceptance. If one adds as well uncertainty in governmental policies, one may sharply reduce the number of innovations that appear to be worthwhile.

Attention is increasingly being focussed on some of the inefficiencies and undesirable effects of the regulatory process. And it is indeed true that the increasing delay associated with obtaining regulatory approval and the uncertainty over future compliance standards cast a severe shadow over more innovative longer-term investments seeking technological leadership. Although the social and economic desirability of regulation is unquestioned, typically a specific goal and approach is pursued with little regard for alternative solutions, of possible side effects, or of effects, or of costs versus benefits of the regulation.

However, I should like to emphasize another aspect of the situation. Our innovative system has worked so well that we have taken it for granted. Little or no attention has been devoted to fostering the vitality or propensity of our economy to innovate. Instead, we have burdened this remarkably productive system with a series of regulatory constraints, obligations, and uncertainties until we can no longer take its vitality for granted. The balance between the positive and negative forces affecting technological innovation appears to be continuing to shift further and further away from the optimum point for maximum public benefit. The lack of a positive influence to coordinate regulatory actions toward achievement of progress deserves urgent attention.

Government actions and policies also, of course, have a strong effect on the rate of inflation. Much has been said about the undesirable effects of inflation, but too little attention has been devoted to its effect on innovation. As noted earlier, innovation is inherently risky and the addition of uncertainties regarding future costs resulting from inflation adds further critical dimensions to business planning that leads to shorter time horizons, heavier discounts on the future, and a focus on lower risk projects. All of these are deleterious to innovation.

The other major arena of government activity affecting innovation involves the availability of resources to invest. I have already noted the correspondence between the drop in effective return on equity and real fixed investment. The central role of government tax policy on capital formation is well known. Since R&D and the innovation it helps generate are a form of investment, the availability of funds to invest strongly influences innovative effort. The basic tax rate, provisions for investment credit, and treatment of depreciation write-off all strongly affect the availability of funds for investment. I believe that the market pull-through of a strong growing economy that is being stimulated by healthy growth in investment is the key factor in stimulating innovation. Special attempts to stimulate R&D in an otherwise laggard or uncertain economy are unlikely to be effective. Many studies have demonstrated that market pull is a more powerful force in determining the success of innovation than technology push.

Although tax policies and securities regulations affecting capital gains and liquidity of venture capital are important to all firms, they may be of even greater importance to new and smaller firms. The strength, dynamism, and accessibility of the U.S. venture capital market have been the envy of the world. Ready access to venture capital and the ability to generate large amounts of cash to finance rapid growth are critical factors in the success of young small firms. Changes in tax provisions and restrictions on security transactions have been promulgated with little regard for their effect on innovation. Under some conditions, the maximum capital gains tax can approach the top tax rate on personal services. This combined with limitations on write-off losses critically alters the risk-reward ratio needed to motivate investment in innovation.

The Securities Exchange Commission in promulgating rules to correct abuses in the sale of stock of young companies has severely impeded the opportunity to regain funds from a successful investment and invest them in another venture. These changes in the risk-reward ratio and reductions in liquidity and mobility of venture capital are a serious impediment to innovation.

TRANSFER OF U.S. TECHNOLOGY

Considerable concern has been expressed about the possible loss of U.S. technological leadership through exports of technology intensive products, licensees, cooperative agreements, and performance of R&D abroad in foreign subsidiaries or joint ventures. Very little meaningful data exist to ascertain the actual extent of technology transfer or its impact on technological leadership. It is important, however, to maintain historical perspective and to understand market realities. Technology transfer is not a new phenomenon. For example, the predecessor companies from which General Electric was created 100 years ago were deeply involved in international technology transfer. The Thompson-Houston Company took the route of joint ventures and vestages of those operations can still be identified in France and Great Britain. Edison took the route of cross licensing.

Electrical systems have historically been closely associated with nationalism. Nations insist on creating an internal capability to generate, transmit and use electricity. Consequently, the creation of a growing local content in the manufacture of electrical equipment is typically a requirement for commercial transactions. Market entry, thus, frequently requires some sharing of technology. General Electric Company Co-production Programs have sought to respond to these realities by taking advantage of economies of scale, specialization, and advanced technology by making arrangements for the inclusion of locally manufactured content in the product when necessary.

It must be remembered also that U.S. companies cannot act unilaterally in technology transfer. Not only must they respond within reason to the wishes of foreign customers regarding technological self-sufficiency, but they must recognize that other countries such as West Germany, Japan, France, and Sweden compete on a technological basis. This technological competition is especially severe in such areas as ground transportation, coal-based electrical generation, high energy density batteries, automation, pharmaceuticals, etc.

In some cases joint technological development may be the only mode of gaining entry to foreign markets. The joint GE SNECMA venture in jet engine development recently discussed in Fortune is such a case. Similarly, the joint production of engines for the Airbus A300 was possible only by sharing technology.

Universal technological leadership is not attainable or economically desirable. The success of West Germany is heavily dependent on her pre-eminence in quality and cost on selected industrial goods, and similarly the success of Japan is based on her quality and cost in consumer goods. Great Britain is eminently successful in science and invention but has been notably unsuccessful in converting these into innovation and economic growth.

In considering policy alternatives affecting technology transfer, we must keep in mind the dynamics of the resource allocation process and the shifts in emphasis that occur in different segments of an economy with the passage of time. Industries and technologies do go through a process of growth and maturation. A key feature of Japan's announced strategy for future growth is to identify and nurture those industrial segments that are younger and more likely to enjoy rapid growth in the future. In contrast, one policy option being seriously considered in Great Britain is to take advantage of the windfall from North Sea oil revenues to rebuild her traditional industries. One might well question which of these two strategies is more likely to be successful.

Any proposal to intervene in international technology transfer should be viewed in the light of its likely effect on resource allocation both within the U.S. and elsewhere, and on the long term viability of any comparative advantage we may be trying to protect.

Here in the United States, I think two factors are particularly important to keep in mind. First, we are probably no longer producing commercial technology faster than the combined effort of all our trading partners. Our estimate is that Japan alone may well have as many R&D scientists and engineers as the U.S. who are working in the areas of economic development and advancement of knowledge. Certainly, Japan and Germany combined have a larger such effort. So we stand to gain from a two-way transfer, with minimum restrictions on both sides, and constraints on U.S. exports typically will not deny advanced technology to third parties. Second, and more important, many U.S. firms rely on foreign sales to partially or totally justify investment in innovation. And many more of us, of course, depend on earnings from foreign trade to help support investment in the future. Both of these circumstances are likely to be even more important in the future. So any effort to restrain the outflow of technology except for clear cut and specific national security reasons most certainly would be counterproductive.

Technological protectionism is not the way to assure maintenance of technological leadership. It would serve to slow our own rate of industrial innovation and, in turn, our international competitiveness.

The NSF studied factors affecting industrial innovation in Japan, West Germany, France, and the United Kingdom. Except in the United Kingdom, industrial managers agreed that there is a close positive link between competition and pressure for effective R&D and innovation -- industrial development. They, unlike their counterparts in the United Kingdom, were favorably disposed toward competition. The Japanese especially welcomed international competition because of the great opportunity for market expansion. (However, they appreciated government shelter and assistance during the time when competitive capability was being developed initially.)

HOW TO STRENGTHEN U.S. TECHNOLOGICAL COMPETITIVENESS

I believe the information that I have presented to you demonstrates rather clearly that the U.S. is, in fact, losing ground in the international market place -- in both technology intensive and nontechnology intensive products. Although our high technology products are doing better than the average manufacture, we are continuing to lose international market share.

I have shown also that our leading international competitors who have maintained the highest levels of business investment, productivity and growth in industrial output are capturing the market shares that we and the United Kindom are giving up. I would not argue that these basically internal considerations are the only factors affecting our international trade. Clearly, such factors as rates of exchange, terms of trade, tariff and nontariff barriers, modes of financing, etc. are also important. Nevertheless, a critically important issue, and one that we can address without the involvement of our international trading partners is: how do we create the investment in innovation that will help allow us to regain what we have lost?

A Better Environment for Investment in Innovation

First, urgent attention is needed to increase the funds available for investment. Changes in tax law should seek to make permanent and more liberal the investment tax credit, provide more rapid write-off of capital investment, and reduce the Federal corporation income tax rate. These actions would increase capital investment, stimulate market pull, and help overcome the impediments of rapid obsolescence and inadequate capital cost recovery.

Further in the area of taxation, any attempt to increase or eliminate capital gains allowances should be strongly resisted. In fact, consideration should be given to reversing recent trends and phasing in more favorable capital gains provisions. While the ability for external generation of investment funds would be enhanced for all companies, smaller firms particularly might benefit from reduction in capital gains taxes. Specifically, a greater spread between capital gains and personal service tax rates, and larger write-off of losses are worthy of consideration. It is not even clear that such a step would create a loss in tax revenue. The data from the American Electronics Association Survey cited earlier, demonstrates how rapidly new firms begin to contribute new tax revenue through both personal and corporate income taxes.

Severe restrictions on sale of stock in venture businesses seriously impede roll-over of capital investments and thus reduce capital mobility. The SEC should reexamine the impact its Rule 144 has had on reducing liquidity of venture capital. It may well have achieved "overkill" in the areas it was seeking to correct.

High priority also must be given to controlling inflation in ways that do not worsen the investment environment. I have tried to make clear that the insidious impact of inflation on willingness to invest in the future is as harmful as the immediate penalties it creates.

The other critical areas in which positive action must be taken to improve the investment climate is our confused and inefficient regulatory process. The government simply must reduce regulatory delays and uncertainties. And in order to maximize the social benefit from our innovation process, a requirement to consider reasonable alternative approaches to and costs of achieving proposed regulatory objectives could help counteract the present single-minded focus on a narrow specific approach and objective. Better coordination of regulatory activities could help facilitate a more timely and effective process. Perhaps we need to create a new institutional mechanism to provide a continuing pressure for progress, and to insure a balanced approach to regulation. The government has had some successful experience with agencies deliberately charged with fostering an industry - in the century old case of agriculture and the more recent case of air transport. What lessons can be drawn from this experience?

More Sensible and Supportive Foreign Economic and Trade Policies

A recent Business Week article (April 10, 1977) surveys the U.S. environment for international business and concludes that our nation's export policies are "feeble and contradictory." Eleven different examples of laws, executive actions, and court rulings that impede exports are listed. The clear and unavoidable fact is that unless a more favorable, well-organized, and stable national policy environment is created for U.S. exporters, the nation will continue to lose world market shares to foreign rivals.

The United States must recognize the realities of foreign trade and try to offset or neutralize the exporting efforts of other governments in ways suited to our own institutional structures.

For example, the Export-Import Bank must be able to offer more competitive financing, and greater protection against political risks of foreign trade and investment is needed.

Our policy should be to encourage - not discourage - expansion of U.S. companies abroad. Our counterparts in Europe and Japan are moving aggressively to do so. They recognize that increasingly a local presence and some form of local participation are pre-requisites to market access.

While some claim that U.S. companies with foreign affiliates are "exporting jobs" and manufacturing abroad to produce low-priced goods to sell in the U.S., less than 7% of the output of foreign affiliates comes back to the U.S., and half of that is from Canada under the automotive pact. In 93% of the cases, foreign affiliates are producing goods for foreign markets, and they are also pulling through exports and providing jobs in the U.S. The General Electric record is illustrative. Our exports to the Netherlands went from $3 million to $79 million in the dozen years since we established our affiliate there. In Australia, they rose from $1.5 to $45 million; and the same thing happened in Mexico, Brazil, Belgium and elsewhere.

And there are many ways to avoid making matters worse. We must guard against technological protectionism and other barriers to competitiveness. For example, since we live in a world of international competition, there should be recognition of this international competition and market place when antitrust laws are applied. Also lengthened licensing procedures and the proposed Environmental Impact Statements for exports for Ex-Im Bank projects could be disastrous to business negotiations. Foreign nations don't need us to tell them they can't drain a swamp!

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Federal Support

There are two areas in which consideration could be given to increased government support - basic research and academic programs aimed at improving productivity. While the measures that I have recommended to enhance longer-term business investment in general could be expected to affect industry spending on basic research, there is strong evidence that industry will always underinvest in basic research relative to expected social returns to the investment. In other words, benefits of basic research are very unpredictable and the funding enterprise typically captures only a small portion, if any, of the benefits of his own investment. Spread over the entire economy, however, the returns are quite large and risk is relatively small. Thus, some public support is perhaps justifiable. Consideration might be given to removing the competitive disadvantage industry has in competing for Federal support of basic research. Also, a government procurement practice worth examining for possible extension is the Department of Defense Independent R&D allowance.

The U.S. lag in productivity improvement is well known and cause for concern. One striking difference between engineering education in the United States and West Germany is in the production of engineering graduates for careers in manufacturing. This tradition is well established in West Germany and notably weak in the United States. Our experience with the Department of Agriculture, DOD, NASA, and the old AEC and HEW - not to mention NSF - all demonstrate that government priorities have a profound influence on education priorities. Consideration might well be given to stimulation of higher educational priorities for educating technical people for careers in manufacturing.

CONCLUSION

Now I've concentrated on two principal approaches to improving the international competitiveness of our manufactured products - and particularly our high-technology products. I've recommended approaches to improving the environment for private investment in technological innovation, and I've discussed ways of encouraging and facilitating foreign trade. I have not suggested large programs of direct subsidy or special write-offs directed to specific industries or areas of technology, and I have not made a plea for more government spending on commercial technology development programs. Let me explain why.

I believe that market pull created by a free and vital economy is the critical factor in stimulating investment in innovation and achieving technological competitiveness. Efficient allocation of resources for commercial purposes is best managed by those who are closely attuned to market forces. The record shows that the private sector does better than the government in planning for innovation where the goal is to introduce commercial products in the marketplace. I would question having government more involved in that process.

Other industrial countries have tried numerous incentives and subsidies directed specifically at R&D, but none has been very successful. What has been learned is that government policies affecting the general economy and climate for long-term investment -- that is to say regulations, availability and price of money, inflation, export and import policies, and general encouragement for private saving and investment -- have been extremely important to the innovation process.

We're really after innovation - not just R&D. Without the necessary market opportunities and climate for risktaking, the results of R&D simply fall into a bottomless pit. The experience of the U.K. exemplifies the problem of government R&D push without market pull and a good investment environment. When you consider that about 90% of the total investment required for a successful innovation is downstream from R&D, it becomes clear why we must concentrate on the overall investment climate.

Let me conclude by saying that, in my judgment, the Federal policy and legislative pot is boiling with current issues that will have a critical effect on this nation's future technological competitiveness and economic vitality. And there are perhaps as many wrong roads before you as right ones. I hope that I have been able to shed at least some light that will be of assistance to you as you face these difficult but crucial choices.

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Senator STEVENSON. Thank you, Dr. Steele.

On some points there seems to be general agreement. In fact, the facts are incontrovertible. High technology generates exports, U.S. investment in technology, and R. & D. is declining; it is declining in relation to investments made in other countries, at least as a percentage of GNP. And the competition is becoming more severe and already the U.S. trade deficit is running at a level of about $40 billion, perhaps more.

The dollar is constantly depreciating. Now, I guess, a little less so. But this seems to have had very little effect on trade. It may be causing inflation; it may be stiffling innovation.

It seems to me there are some other influences at work that I would like to get your comments on. The American exporters are big companies; General Electric is the biggest exporter, I believe.

Dr. STEELE. That is right.

Senator STEVENSON. The little technical companies in the recent past have about disappeared. According to the Commerce Department, creation of new, small, technical companies has reached zero. The large companies may be in a better position to make long-term investments in R. & D. They have greater access to capital, perhaps they can absorb risks more easily. They pretty clearly are more interested in foreign markets, in a better position to respond to foreign demand, they have marketing systems available to them.

Our hearings have indicated that the typical small business in the United States just doesn't take exporting very seriously. It is intimidating to them, which I can understand because they have relied on the domestic markets. Instead of just relying on traditional structures, it seems to me there might be some lessons to be learned from the experience of other countries who seem to be overtaking us at the moment.

If so, that exercise would, I suppose, involve reexamination of traditional structures. The Japanese don't, as we do, as has been indicated, require everybody to subsidize everybody else through the Government, with the result that everybody pays. They are very selective.

In the case of data processing, the Government reorganized industry, and it financed the research in data processing; it finances the operations to some extent of the industry. It adapts its trade policy to help infant industries and its tax policy to provide tax incentives to industry, and next year the Japanese industry confronts IBM with the fourth generation of computers. That is about the highest technology, I guess, that there is.

Now my question to you is the size of this phenomena. We in the meantime are trying to break up IBM. Not only is the investment in R. & D. declining, but the Antitrust Division of the Justice Department is trying to bust up IBM, maybe, instead of letting it go the traditional American route, with all it implies about the adversary relationship between Government and industry, and we ought to be facilitating the combination of large industries which can make the research, or industries of comparable size to IBM, that can make these investments in R. & D. and can market on a global basis in competition with, for example, not the electronic data processing industry, but the great trading companies of Japan, which can absorb exchange rate losses, also profits, and beat price competition on a global basis.

How do you respond to that general proposition? I think what we have to do is facilitate larger economic aggregations, like General Electric and IBM, if we are going to make the investment in technology, if we are going to respond to demands throughout the world to market our products.

Dr. STEELE. Mr. Chairman, I can comment on that, if I may. I think it is disturbing that in considerations involving antitrust, technological viability, if you will, is essentially ignored as one of the factors that should be taken into account. I think both in the case of IBM and also in the case to break up A.T & T., the implications of what that might mean for Bell Labs, and whether Bell Labs can survive as one of the most productive technological organizations in the world, are either not considered at all, or considered to a very minor extent compared with other factors.

I think we can simply no longer afford to do that. We do have to consider technological viability as one of the aspects of worldwide competitiveness.

I think in the same sense, the decision in the Kodak-Berkley Camera case didn't take into account that the real benefitters might be the Japanese companies. The Japanese were already over here marketing photographic products. Requiring Kodak to announce 18 months in advance its future technological innovations is going to provide that information for the Japanese as well as everybody else.

There is clear evidence that the Japanese have already capitalized on that in a major way.

I am not saying we shouldn't still be very much concerned about the competitive climate in this country, but it is a world climate, and the competitors are world competitors, not necessarily just domestic.

Senator STEVENSON. Yes. I think that is the point, instead of the relevant market being, as it has traditionally been, a local or maybe a national market, it is becoming a global market and it should become a global market. Any other responses?

Dr. BARANSON. I think I would agree with Dr. Steele that we certainly need an intensification of the competitiveness of U.S. industry vis-a-vis trade adversaries. I don't think necessarily that this means we have to move to further concentrations of industry—that because there is a certain economic advantage in size, that it is only the large American firm that needs to be reinforced.

I am not sure that even further relaxation of the antitrust laws, moving in that direction, is the answer. The spinoff from IBM is an example of a small firm that was inhibited by the presence and the possibility that IBM could further move in and challenge its technology. I do think that we have to look much more realistically at the realities and to recognize that certain legitimate collaborative efforts within and among American industry may be not only useful, but indispensable in order to hold our own against trading adversaries. I do think that if considerations are given to refinement of tax and credit instrumentalities, that special attention should be given to small or medium firms that are sufficiently small but technologically viable. I think the efforts should be to reinforce their ability and motivation to commercialize technology.

We also could benefit from more Bell Labs—perhaps collaborative efforts jointly funded by the U.S. Government and private industry. Special exemptions from antitrust laws may be needed in order to move in that direction. What are needed are mechanisms that permit necessary and legitimate collaborative efforts within a competitive framework.

Dr. HEISS. I very much agree with the comments just made. I would like to introduce, maybe, one or two aspects a little bit on the borderline of the issues.

One function of federally funded R. & D. I feel very strongly is to push innovation in industry. If we recall the introduction of some very advanced basic technology in the commercial sector, like communication satellites, it was often at the initiative of Congress and the Federal Government that technology really got pushed onto the industry.

The fact is that industry—in each sector differently—tends to be conservative, particularly large companies are, and rightly so, very conservative with regard to the funds allocated, the initiatives and innovations that they want. It is a process of oblescence that introduction of new products creates, and I, for one, am not totally sanguine about the great role of privately funded R. & D, as against the important role I tried to outline earlier that federally funded R. & D. has shown to have in the international trade position of the United States and their individual industries.

The role of the Federal Government in funding R. & D. ventures needs to be emphasized as it has done. This funding has to occur at an increased rate in order to push innovation in the economic system. Such funding need not be concentrated in any one single area.

In judging the need for Federal funding of R. & D. one should not overlook some of the oligopolistic character of much of American industry and the American economy. On the labor side, unionization and protectionist elements also contribute to rigidity and resistance to innovation. In discussing technology and international trade issues, we should not forget the great contributions other countries have made to the United States in the past, with regard to new ideas, know-how, innovation, and foremost, scientists and engineers, in a climate of free trade and free flow of knowledge. There were few barriers there, few prohibitions, except by some countries. In discussing these issues of free trade, we should be mindful of the principles of free markets. But in order to sustain that belief, the United States has to have an aggressive R. & D. world technology policy. It is not labor where we have the competitive advantage, it is not any more in capital markets where we have a competitive advantage. The one remaining key factor of U.S. competitive advantage is know-how and technology. And there we are not running as fast as we ran in the 1960's both on the Federal and the private side. What the United States needs is (1) a full development and (2) a full employment policy of the U.S. science and engineering capability.

Finally, the belief that privately funded R. & D. is a solution to everything is incorrect. Such R. & D. should be stimulated, but often such R. & D. is not that exciting or advanced. Some of the R. & D. that goes on in car companies—the largest portion private funding of R. & D. comes from the American car industry—may be of questionable quality: a Honda, a Datsun, and a VW diesel still are preferred in world markets and the United States. What is that R. & D. doing?

One has to ask critical questions also of privately funded R. & D. I don't know what automobile R. & D. is precisely, but a lot of it must be restyling, painting cars differently, et cetera.

Senator SCHMITT. A catalyst.

Dr. HEISS. Yes. Hence the important role of federally funded R. & D. as a push to innovation. There exists maybe a funding gap of between $10 and $15 billion in that effort, if we compare today's dollars to what we did in the 1960's.

One should not be flippant about dismissing the role of federally funded R. & D. too quickly. Yet many economists are so, in the absence of precise qualitative evidence. Budget consciousness is very important, but one has to have substantive programs in the U.S. economy to at least maintain the technological position of the United States in world markets.

This includes opportunities for innovative space technology that can play an important role in maintaining, or even expanding, the U.S. technology position.

The concept of venture R. & D. companies, with the provision of being able to write off say three times the initial investment would do a lot to stimulate innovative—small R. & D. ventures in the private sector. Such ventures would then be able to find better financing: If the banks know that three times the initial investment will flow back to the group they are financing, before Federal income taxation takes effect. Such a provision will also help large companies in some distinctive ventures, and improve R. & D. ventures in the private sector. It is not a free-for-all. The venture groups would have to come and say look, we are proposing this R. & D. here. It is not just painting the same antipollution device in a different color. The proposed venture would have to go through some evaluation process. As much as we dislike that, one would have some agency or a multiplicity of agencies to agree that the proposed venture is relevant research.

Finally, one of the greatest inhibitors, I believe, in the energy area of innovation has been price controls. How can one expect large innovative investments in energy R. & D. if at the same time one controls all types of fossil fuel prices at artificially low levels?

In Germany, for example, the absolute energy consumption—the absolute, not relative—level has declined ever since 1973. That was not done with the creation of a Department of Energy, it was not done with the creation of any other agency, it was a simple belief in the efficacy of the market pricing mechanism, as well as energy initiatives and funding of R. & D. projects. The belief in free market principles is important when judging R. & D. technology and trade issues. Price controls, as well as inflation and depreciation rules, have a strong adverse effect on the ability to innovate, if not the willingness to innovate.

Senator STEVENSON. Mr. Douglas?

Mr. DOUGLAS. I am often puzzled, Mr. Chairman, by the recurrent statements that small firms do not have participation or a place in technology exports.

In the case of the data processing industry, superelectronics to a certain degree, but data processing is the one we know well, that does not seem to us to be the case. In California in the Santa Clara Valley, where much of American's semiconductor and data processing industries are located, we find these firms who provide components, who provide designs, who provide subassemblies, do participate very directly, either in licenses and royalties, or in manufacturing as subsuppliers.

I don't know whether it is truly important to revive any high technology exports in high earning areas such as the data processing. If we want to feel we are going to counter a Japanese or West German thrust into markets where we already have a strong position, indeed into the domestic market, where we have had a commanding position, whether it is really going to pay you back very much to try to take small or medium firms, who may not even want to become directly involved in exports, who have engineers or technical people or entrepreneurs who wish to devote time, energy and capital to innovation and not to marketing, and creating sales and service outlets abroad.

On the question of bigness, and your reference to IBM and other companies of that size, GE, and the implication, perhaps, that they are more capable than small to medium firms in exporting, I really don't see that to be the case.

In fact, I would say that the IBM's, maybe the GE's of the world, pose a kind of political or industrial threat in certain market areas that have a negative consequence.

Senator STEVENSON. Thank you. Senator Schmitt.

Senator SCHMITT. Thank you, Mr. Chairman.

First of all, I would like to underline what Dr. Heiss said about the export of the products of high technology, rather than concentrating on the export of high technology itself.

He has mentioned several examples, obviously many of them come from our space experience, but there are certainly others. That is the part of my opening statement that I did not read, and I would just refer you to that.

Also I would like to introduce another concept that we have not discussed. It is not a new concept, but something we have not discussed today. That may be considered a nuisance by some, but it is extremely important. The concept is the difference between the funding of research development and demonstration and the funding of research and technology.

The vast growth of our aeronautics industry was not based solely on the Government funding the building of airplanes. At least the commercial side of it was based in large part on the Government funding certain focused areas of technology development. The Government and GE and Pratt & Whitney, acting through NASA or the old NACA, were really focused technology groups working together, sharing laboratories, working out specific kinds of problems, wing problems, engine problems, and so forth.

I think it is important that as we look at what funding the Government should put into R. & D., we should look into the type of funding. One of the major deficiencies in our energy program today is a lack of Government funding of the focused subcategories of technology that are required for energy efficiency and energy production.

For example, I and others have tried for many years to get certain aspects of fuel cell technology funded by the Government because of its future importance as an energy technology.

There has been a great reluctance to do that, but it is a technology development type of effort that I think we have to remember has been very, very important in stimulating the kind of export technologies that we have had in the past.

Finally, I would just ask one question, and that is to ask each of you to comment on the nature of your recommendations for coordination of trade-related policy at the Federal level.

As I indicated in my statement, and it was mentioned in the Business Week article referred to by Dr. Steele, there are a lot of these policies that seem to be at cross-purposes. The fact is I know that Federal policies work at cross-purposes.

How would you see us developing within the Federal Government a strategic capacity to coordinate these kind of policies?

There is a proposal before the Senate to create a Department of Trade. I will be frank with you, I don't think that is the answer. Most departments just shuffle boxes and don't solve any problems. But it may be we need something at the Federal level that creates at least the incentive, if not the requirement, that there be coordination of agencies that have major input into trade-related policies.

Would you gentlemen care to comment?

Dr. Heiss. Not having been entangled in some of the difficulties described by others here today, I think essentially all of these export controls should be abolished, including the offices that carry them out.

Senator Schmitt. Well, that is one answer.

Dr. Heiss. I am very serious on this. This is a totally make-work, paper-shuffling operation, wasteful of taxpayers' money, and in addition contrary to true U.S. long-term interests.

On the strategic side, a very important issue is at stake; the Department of Defense, jointly with industry and Congress, can take care of those strategic issues.

Senator Schmitt. If I may interrupt, I would like to clarify something I said earlier. When I said strategic capacity, I didn't mean Defense. I meant strategic in a general sense applicable to trade.

Dr. Heiss. Right. In the second sense, the defense sense, I think the Department of Defense can handle that, the White House can handle that, and the Department of Commerce should essentially be legislated out of anything in that area. I am very, very serious on this. These issues of export controls go back 200, 300, 400 years, in the history of economics. These measures have proven to be counterproductive, wasteful, again and again. Whoever conceives and carries out such regulations does not earn his or her salary.

Not that they are not good people, they are just hurting U.S. interests.

Senator STEVENSON. Will you yield? I don't understand what you are suggesting, Dr. Heiss. You said let DOD and the White House take care of it. What do you mean by "it"? Are you suggesting no export controls for strategic purposes?

If the Congress and the administration feel that there is a role to play for the Federal establishment in international trade, then it probably ought to be the Commerce Department playing that role.

Dr. HEISS. My company and I personally make no bones about feeling the Department of Commerce is one of the most God-awful conglomerations of jobs and make-work that exists in the District of Columbia. It is almost unmanageable.

Mr. DOUGLAS. But export control is a subject we have to live with very closely. I would have some differences with Dr. Heiss. We are not the biggest rooting section for export controls as they now exist, but we have come to feel that in certain areas of computer technology, which is our key business, there are reasons for it to exist.

Whoever the executive agency is to be, whether DOD takes that over, or Commerce takes that over, that is a question that really would not make too much difference one way or the other.

Senator SCHMITT. Let me interrupt and say what I am getting at. Are there a diverse set of trade-related policies enforced by the Department of Commerce, by Treasury, by State Department, by the White House itself, by Export-Import Bank, by the Federal Reserve Board that have very profound consequences on our trade picture? Whatever we may think about Commerce, Commerce can't control what Treasury does, or what State does, or what DOD does, or what the White House does. I think the testimony before the International Finance Subcommittee has been clearly shown that there is a complete absence of any high-level coordination of those various policies, and they often work at cross-purposes.

Treasury wants to milk every cent they can out of our trading partners. Commerce may be trying to do things right, but they have a tremendous bureaucracy to work with. The State Department is interested almost entirely in the foreign policy benefit, and often just the short-term foreign policy benefits, of a particular transaction, and so forth, right down the line. Everybody has a different interest that they put the blinders on that and that is the interest they follow.

How can we provide some kind of tightened incentives, so there is some kind of coordination among these different policies?

Mr. DOUGLAS. The mind almost rejects the thought of a new Federal program without bureaucracy. I think the business community is very well aware of the problems, of the hydra of trying to get anything coordinated in an international sense in the District of Columbia. I think most of us would be very supportive of a congressional move to create a focus with muscle, whether it is a new department or in an old department. What many of us fear with historical reason is that while this goes on, 1 year, 2 years, two sessions, three sessions, our trade position, the investments, our ability to accumulate capital, to hold the money and the people, continues to decline. By the time we finally get around to a massive reorganization, and an optimal plan, a lot of us may be out of business. We don't plan to be out of business, but I am speaking in a general way.

I think any program that touches international trade, international policy, requires an extremely strong and perhaps unusually continual oversight and involvement of the Congress. Really the private sector is not too sanguine with turning it over to the established Federal bureaucracies in the District of Columbia and having anything new come out of it. We would like to have your strong involvement.

Senator SCHMITT. Dr. Steele?

Dr. STEELE. I was going to say there is a missing concept in the organization, I think. I don't know how one can go about implementing it, but in industry, and in some aspects of the Government as well perhaps, but in the ad hoc temporary sense, we have the project manager whose job it is to get the job done, not to represent any particular special interests, but to get the job done. In the continuing sense in industry we have the general manager for a sphere of business whose task is the same thing, not to insure manufacturing is the best, or marketing is the best, but to get the job done.

That concept of a person not protecting a special interest but just insuring that you move rapidly and expeditiously to achieve an answer, that organizational concept is missing.

I don't know how one includes it.

Mr. DOUGLAS. Correct. In many ways what Commerce seems to be burdened with, what Frank Wile's organization in Trade Administration seems to be responsible for, but apparently on a day-to-day basis, without sufficient muscle and authority to get it done.

It looks terrific, and I think Commerce's intentions in most cases are really very good, but the results are not commensurate. And they are frustrated, we are frustrated, Congress is frustrated, because that is not what you mandated them to do. In the meantime, what happens?

Senator SCHMITT. Well, they can't do it if they can't exert influence on the Secretary of the Treasury, the Secretary of State, and so forth. Yes, Dr. Baranson.

Dr. BARANSON. Just let me add briefly to what the other panelists have said. I think that in the area we are discussing, to leave the technology decisions to the marketplace at this point in time would be a mistake. The question is to what degree will you introduce administrative controls of one kind or another, as distinct from efforts to influence market decisions.

I think that we ought to move in the latter direction. I share with my colleagues their observations on the difficulties of coordinating policies on an interdepartmental basis, especially in this extremely complex area. It is particularly unmanageable at the project level.

Senator SCHMITT. Let me say, it would not be unmanageable if there was coordination from the White House. But we haven't had that kind of coordination in this area.

Dr. BARANSON. We have a special problem of administered guidelines to industry here in the United States. The situation in Japan is quite different from ours. The Japanese have for several decades now been fairly effective at Government involvement in industry decisions. But even in Japan, they have interdepartmental problems, and industry does not always adhere to Government guidelines. To think we can duplicate even the degree of coordination the Japanese have would be unrealistic.

Senator SCHMITT. I don't think we can do it their way, but I am not willing to admit we can't do it at all. We couldn't do it their way because we are culturally two completely different societies.

Dr. BARANSON. I think the Congress should consider a purposeful effort to influence decisions in the marketplace, including the question of cost-sharing of technical innovation and the special lines of credit. I think it is important to draw out segments of industry that are willing to think more about designing and engineering for the U.S. economy.

By the way, I think it is a mistake to single out exports from the larger issue of competitiveness of U.S.-based industry. The same applies to import controls, rather than looking at the whole competitive position of U.S. industry and the various ways in which it is impacted.

One other point: There have been several examples cited of the German and the Japanese Governments sharing R. & D. costs and providing special lines of credit for breakthrough technological development.

I think we should try to find more American equivalents, as we have done it in areas of atomic energy development and in the early days of aircraft and communications development. In the 1920's, the U.S. Navy needed a totally integrated communications system, and RCA was funded almost exclusively by our Government to design and develop the necessary equipment. We need to do more of that, I think.

I also think that on the question of Government-funded R. & D., we need to distinguish between areas in which industry is encouraged to develop a military or space prototype and the eventual development of a commercial prototype. The funding of an exotic piece of industrial hardware is a long way from commercializing that product and competing with the Japanese.

You will find in the case of Japan that they don't have the defense spending we do. When they organize a computer equipment program or something like their new magnetic-field train, they are looking toward the commercializing of Japanese-based industry to develop the basic designs and capital equipment, so that Japanese industry and Japanese employment and foreign exchange earnings will benefit.

I think that is the direction we ought to go. We ought to influence the marketplace, rather than follow the path of administrative controls.

Senator SCHMITT. Mr. Chairman, frankly, I don't agree. I think that there are certain major projects of national interest that the Government is going to have to invest in and work cooperatively with industry to undertake. In other areas, I think the Government's role can be primarily one of establishing a research and technology base from which a variety of areas of innovation can grow. I really believe that U.S. industry is perfectly capable, if not more capable than any other industry in the world, of determining where the markets exist and where the investments they should make ought to go in order to be competitive.

If they can't, they will fail in the marketplace. Thank you.

Senator STEVENSON. Senator Proxmire.

Senator PROXMIRE. Dr. Steele, following up on the latest colloquy, I take it that you feel that we should hold the Federal spending for subsidizing in a big way technology research to a minimum.

As Senator Schmitt pointed out, there are certain areas where there is no way we can avoid it. We obviously have to have heavy expenditures in defense. That is the heart of our defense, our technology. We have to spend a lot of money there, and we are going to spend a lot of money there.

Energy is the same kind of thing now, whether we like it or not, obviously the Federal Government is committed to a huge research program. I think we authorized over $10 billion to be spent over the next few years at a rate of $3 or $4 billion a year in energy research.

Space is something where we have made a commitment, rightly or wrongly, to spend a certain percentage of the budget, and we seem to be committed to that, come hell or high water, and that is it.

Obviously in the environment area, National Science Foundation and others are doing research. And we have to do that.

You are saying except for that, as I understand it, what we need really is a healthy demand pull market, plus a good investment environment. Is that right?

Dr. STEELE. Absolutely, Senator. I believe what we face is a sort of general malaise, and I think it would be a serious mistake to enact a series of highly specialized programs to attempt to deal with it.

We are dealing with a complex subject; the second and third order effects of what we may be creating will be almost impossible to anticipate and take into account.

Senator PROXMIRE. Isn't one of the biggest villains, though, Government spending?

Dr. STEELE. Yes.

Senator PROXMIRE. From every standpoint, both inflating the demand sector, in having erratic movements, and also discouraging investment?

Dr. STEELE. Yes, sir. A great deal of comment has been made this morning about what other countries are doing in this respect.

On the other hand, we shouldn't just limit ourselves to Japan; we have a number of other competitors, each with a different history. If you look at their programs trying to stimulate R. & D. over the last 15 or 20 years, you discover they have changed their programs a lot. They have tried a lot of things, which suggests they themselves are not necessarily very satisfied with the results.

Senator PROXMIRE. They started out copying us, as somebody pointed out, almost religiously, very carefully.

Dr. STEELE. That is correct. And no effort has been made in each of those countries to go back and look at the effects of the programs they have undertaken. So we really don't know very much even in the other countries about how effective individual programs to try to stimulate R. & D. or technology were.

In Canada for the last 15 or 20 years they have tried a series of things to stimulate R. & D. I have talked to Canadian Government officials, and they have a good deal of reservation about what has or has not worked, whether any of it has worked very well.

Senator PROXMIRE. We do have a situation that Japan in one way or another has created a situation where they have a phenomenally effective export situation. They have done that with a much sharper increase in wages than we have had in this country, as you know.

Dr. STEELE. Yes; that is correct.

Senator PROXMIRE. And with also terrific domestic inflation. Yet they have been able to achieve that export advantage.

Dr. STEELE. But also in a climate which has been generally very stimulative and supportive of economic growth and productivity, in the general sense, not just highly targeted to specific industries and technology alone, but that is embedded in a much larger framework of support.

Senator PROXMIRE. Now, Dr. Heiss, I am somewhat puzzled by your presentation. I wasn't here when you gave your paper, but I have studied it. You recommend more research and development in defense and space, but I don't want to be unfair, you are not saying, or are you saying, that we should engage in this for the fallout benefits, as well as for the absolute requirement we have to have a substantial amount to maintain an effective defense and space program?

Dr. HEISS. Let me take a little bit of time in answering your questioning.

On page 96 I show a breakdown of federally funded R. & D. that you asked for earlier, between civilian, defense and space R. & D. funded by the Federal Government. The breakdown shown is in constant second quarter, 1972 dollars. It aggregates the funding of 5 years each for the past 20 years and includes fiscal year 1979—1960–79.

Now what the numbers show is that in defense the total funding of both 5-year periods in the sixties was around $51 billion; that has dropped by $7 billion in the first 5 years and by $9 billion in the second 5-year period as proposed now, of the seventies.

Now, if the country's position is that it is technology in defense that keeps us ahead of others and not quantity of tanks and planes, then I see a certain contradiction here in the funding we provide in constant dollars to that effort. That is all I am saying here.

Senator PROXMIRE. Well, supposing we come to the conclusion that—maybe a wrong conclusion—but nevertheless the President of the United States and the Congress come to the conclusion that what we need for defense is less. Maybe that is wrong, a lot of people think it is wrong, but say what we need is less.

Are you saying we should spend more than we spend here because of the beneficial effects it will have on the civilian technology?

Dr. HEISS. Let me draw your attention to page 94.

Senator PROXMIRE. But how about an answer to that question.

Dr. HEISS. OK. The results for total industrial R. & D. are presented on page 94 for 1975; these findings do not change much for each of the past 18 years. In addition to total R. & D. funding performed by industry, we also looked at federally funded R. & D. in each sector of industry and related that to the U.S. trade position, export intensity, and net trade—export minus imports—for the past 20 years, 1960, 1965, 1970, 1975. The Federal R. & D. results are stronger than total R. & D. in their apparent effect on the U.S. trade position for the past 18 years. These preliminary findings are not included in my testimony; it is research we hope to have completed in about 6 months.

Senator PROXMIRE. That is the one area where you should be able to see the connection, if anywhere, in the export of what the Defense Department produces or pays for, F-15's, tanks, planes, and so on?

Dr. HEISS. Yes.

Senator PROXMIRE. We have just explored the export in that area. It has greatly increased since 1970, the sales abroad have gone from $1 billion to $10 billion.

Dr. HEISS. The aerospace industry is one of the few areas where the United States is still truly competitive in world markets, because of very substantial Federal funding, which hasn't occurred in other areas, where we are losing out. That is precisely the point. It is shown on that graph. Aerospace industry—other than agriculture, which depends on accidental movements of crop harvests in the Soviet Union—aerospace is the strongest gross export and net export component of the U.S. balance of trade, consistently over the past 20 years.

I think one reason for that is the Federal funding of R. & D. in those areas.

Senator PROXMIRE. You are saying as far as the aviation industry is concerned, for instance, the manufacture of planes, that we should have an explicit amount of funding for that particular purpose to buoy up that industry, Federal funding?

Dr. HEISS. Well, we have it. We also have it in other areas, such as communications.

Senator PROXMIRE. I am not so sure. The global figures don't tell us how much of that went into aerospace. After all, much of the space program is not related to the aviation industry. Some of it is, but how much of it? It is a relatively modest amount of the space program. And I suspect it is a relatively modest amount of the aviation program.

Dr. HEISS. Take communications, for example. Communications as you know, the total in the United States, A.T. & T. alone has invested $100 billion in fixed plant and equipment, and they have net investments a year of $10 billion. The space-related communications segment as of today is $1 billion of net investments, and a net revenue is about $500 million.

If you look at some of the space projects now before us, very significant initiatives are being proposed in the communications sector. It has nothing to do with prestige. These are specific, well-thought-out, and studied programs, which will need major Federal funding in the areas of commercial worldwide global applications.

Communications is one. Another area is worldwide resources inventories, including crop information, where the United States has been again and again taken advantage of by other countries that have monopolistic crop information. These issues involve huge amounts of dollars. Second, we can establish global information systems, public information, not monopolized by any one group or country. These initiatives will require very innovative advanced new R. & D.

U.S. industry knows how to do it if the funds were there to do so.

Third, the ability to construct large structures in space—I am singling out space because you seem to have a hangup on it—the ability to construct massive structures in space is made possible only by the space shuttle program. I was before your committee in 1971 and 1972, and you may remember the story of the space shuttle is not transportation costs. I told you so then, and again I make the case——

Senator PROXMIRE. I don't want to get into that. The Appropriations Committee of which I am chairman is responsible for the NASA budget.

Dr. HEISS. You see what happens with the space shuttle is the United States will be able to construct massive structures and sustain high reliability levels of operations in space which today are certainly not possible. With that, the United States has the opportunity of some revolutionary advances in technology, with commercial orientation, worldwide applications, which I think are part of the current opportunity the United States has in the technology area, be it in international trade or be it for domestic applications.

Now, the fact is that if one looks at the figures as they are, the areas where R. & D. funding has been strong and Federal R. & D. funding has been strong, the United States remains competitive strongly in world markets.

I am not saying the only explanation is R. & D. and innovation in defense or space. In the energy area, some of the R. & D. is defense related. I am saying, however, defense and space R. & D. are one important contributing factor to the sectors where the U.S. economy is strong in international trade. Yet, if one looks at the R. & D. funding numbers as a percentage of GNP—I refer to page 99—that is, the relative emphasis the United States puts on funding Federal R. & D., the story is we have cut back by 50 percent in defense; in space we have cut back threefold; in Federal funding of civilian R. & D. we have increased the effort about 50 percent. All these measures are in terms of the percentage of GNP, the relative emphasis that we put on R. & D. as against other activities that go on in the economic system. Instead of GNP, one could use some other national income figure, private income, et cetera. The GNP measure is indicative of where the relative emphasis of Federal R. & D. funding went.

The emphasis in Federal R. & D. funding is in the wrong direction, if one believes the premise that the advantage the United States has today is in technology, in know-how, and not any more in labor—other countries have many more people—and no longer in capital—other countries have as much as are more supportive of capital formation.

The question is not just cutbacks in Federal R. & D. funding, and then industry will pick up the slack. That has not happened in percentage terms over the past decade. In absolute dollars, there was an increase in industrial R. & D. But industry is still only allocating 1 percent of GNP, roughly to R. & D. In addition, industry is very conservative as to what innovations it wants. The development of small companies in R. & D.—and other ventures—in the 1970's is a worrisome phenomenon, the free entry argument which is used in defending current market structures in various industrial sectors, I think, hasn't been quite working recently.

Senator PROXMIRE. It is an interesting theory. I just think you have to justify every appropriation on its own merits, whether that specific appropriation is worthwhile or not.

Dr. HEISS. Absolutely.

Senator PROXMIRE. And the vague notion that somehow this is going to help our exports, you build a pretty good case, I must say, but I will have to determine it in my own judgment based on whether or not a particular appropriation is justified relating to what it would do.

Dr. HEISS. Absolutely. I think the departments can be subject to such accountability. I think they could. But one thing that inhibits the departments is that they believe they live under some absolute funding limit. Due to this perception, sometimes they do not propose really innovative projects that would require a large increase in funding. I think it is one phenomenon that maybe should be broken up a little bit.

Dr. STEELE. I think the aerospace situation is very interesting. I think we really have to look at specifics, not generalities. The 707 was developed from the KC–135, and the DC–8, DC–9, 727, 737, 747, L–1011, DC–10 were all developed with civilian money for civilian markets. True, they benefited from technologies as Senator Schmitt pointed out. But they were not Government-financed R. & D. programs.

The other part of this problem also is that one of the reasons they were developed is we had a healthy growing economy, with relatively profitable airlines that were interested in trying to expand their capacity. You did have a Government agency, the CAB, that was interested in nurturing the growth of the airline industry. We had an economy in which passenger miles were growing rapidly, so you had an expanding market.

The market pull led the Boeings and McDonnell Douglasses to want to develop products to take advantage of it.

Senator PROXMIRE. That makes sense to me.

Dr. HEISS. Of the aircraft you just mentioned, there are only two outstanding technologies that made that possible: large-engine and wide-body technology, and both of them were financed by the Department of Defense very early on. Anything else in these planes is new paint and a little bit of different styling; no truly new technology, other than what was financed by the Department of Defense is included in these airplanes. This is one of the big sorts of bad fallouts of the SST debate. I am against the SST, but——

Senator PROXMIRE. We agree on something at least.

Dr. HEISS. The testimony presented at that time on the SST goes into some of these judgmental exercises. It is not true that the technology needed for the 747's was financed by private companies. It was financed by the Federal Government.

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Senator STEVENSON. Dr. Steele, you got into the specifics, after which you said you shouldn't have. Would you get the Government out of NASA, and all support for aeronautics?

Dr. STEELE. No, sir, I very much agree with the position Senator Schmitt took that basic technology development, which doesn't necessarily have particular commercial implications or applications is an area where Government participation can be helpful.

Senator STEVENSON. How about agricultural research? Would you get the Government out of all agricultural research?

Dr. STEELE. No, sir, the same thing.

Senator STEVENSON. As a farmer, I don't know what I am farming for.

Dr. STEELE. I am talking about the Government-supported R. & D. behind it.

Senator STEVENSON. How about health? There are certain commercial implications there. Would you get the Government out of all health research?

Dr. STEELE. No, sir.

Senator STEVENSON. You wouldn't get it out of all basic research, the national labs?

Dr. STEELE. No, sir. As a matter of fact, my paper indicates I would support Government efforts to increase the amount of effort on basic research.

Senator STEVENSON. What you really support is tax incentives for everything? You don't want to repeal any, do you?

Dr. STEELE. I haven't thought about that. I am concerned about specific tax subsidies looking to increase R. & D. as such.

Senator STEVENSON. You like those?

Dr. STEELE. No; I do not like them. What they are likely to do——

Senator STEVENSON. You don't think they should be able to have a writeoff either by deducting it as an operating expense or writing it off as a capital expense, the investments in R. & D.?

Dr. STEELE. Of course. That is not a subsidy, that is an operating expense of doing business.

Senator STEVENSON. You want to keep that?

Dr. STEELE. Yes.

Senator STEVENSON. You think those subsidies or incentives are sufficient to encourage industrial innovation and investment in R. & D. in the private sector?

Dr. STEELE. I don't regard the recovery of legitimate costs of doing business as a subsidy.

Senator STEVENSON. Well, do you think the tax situation at the present time offers sufficient incentives to industry to invest in R. & D.?

Dr. STEELE. I would have to say yes in so far as they apply specifically to R. & D. At least in looking for additional things to do, that would be well down the list. I would be much more concerned if you want to get into tax incentives, about those that stimulate investment in a more general sense, that would lead to the growth in the economy.

If people see a growing economy, they will look for ways to create technology to take advantage of that growing economy.

Senator STEVENSON. So you support an increase in the investment credit?

Dr. STEELE. Yes, sir.

Senator STEVENSON. For everybody?

Dr. STEELE. For everybody.

Senator STEVENSON. Of course, everybody pays for it.

Dr. BARANSON. Senator, on this general question of whether increased Government funding for R. & D. should take up the slack from industry, I think I would lean in the other direction than what has been suggested by Dr. Heiss.

I think what needs to be done is to further encourage industry to take the risks in R. & D. and in new industrial plants. And this is an area where you have to get down to specifics. There is no question but that the space communication systems, the basic research on the feasibilities of communicating through space systems, and on the launch vehicles, required the kind of Government funding that no individual firm could possibly do. But from there on out, the commercial applications of satellite and ground station equipment, along with other communication equipment spinoffs, have been developed by private firms—an area where the Japanese industry has increasingly taken over segments of the market.

If you go to a space satellite station here in western Maryland, most of that is equipped by Nippon Electric, not by General Electric.

The new facsimile systems that can use used worldwide are largely being commercialized by Japanese firms. Many American firms are marketing such equipment, but it is largely being designed, engineered, and produced abroad.

So I think what needs to be reinforced is private industry's incentive to commercialize the technology and particularly in terms of U.S. production. I do not think that Government spending, except in a special sense, which I mentioned, can take up the slack in this area.

Senator STEVENSON. Well, we have had a long hearing, and it has been very helpful and useful. I think Dr. Heiss made the point about space. We have made an enormous investment in space, the Government has, over $12 billion for the shuttle. And the public, including Members of Congress, associate the whole space program with space spectaculars. We are just at the edge of realizing the benefits of that investment.

Everybody supported the space spectaculars, but they have a hard time agreeing to support the benefits for mankind and for the United States.

Of course, they aren't very spectacular, but when you look at them, they are very spectacular and very exciting. We have lost our vision somewhat at least, we need imagination and initiatives somewhere along the line. I am afraid our sights aren't as high as they once were.

Thank you, gentlemen. It has been a good hearing, it has been very helpful. We are grateful to you.

The committee will stand adjourned until tomorrow morning.

[Thereupon, at 1:05 p.m. the hearing was recessed, to reconvene at 10 a.m. the following day.]

[Additional material received for the record follows in the appendix:]

APPENDIX

STATEMENT

by

Dr. Bruno O. Weinschel*

on behalf of

The Task Force on U. S. Innovation in Electro-Technology
of the U. S. Activities Board,
Institute of Electrical and Electronics Engineers, Inc.

To

The Senate Subcommittees on:

Science, Technology and Space; and

International Finance

Concerning

U. S. High Technology - Impacts on U. S. Policy

Affecting World Markets

May 16, 1978

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Acknowledgment

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Executive Summary

In this document we have attempted to provide a brief review and evaluation of current U. S. policy concerning the development and commercialization of high technology, and suggested possible measures for improving our position. The essential points of our findings as they relate to the questions posed by the Joint Committee, may be summarized as follows:

1. There is a significant correlation between levels of R&D investment and the maintenance of U. S. technological leadership. There is no such strong direct relationship between U. S. exports of goods and services derived from such investments, but there could be if the time-lag prior to implementation and commercialization could be decreased.

2. Private investments in R&D in the U. S. are generally declining, and this has serious implications for high technology exports. The factors contributing to these trends, however, are many and complex, and are discussed in the body of this document along with recommendations for policies which may provide incentives to increased these investments.

3. If we over-simplify our comments, we could say that the role of the small firm is larger in the innovative process, but it is less equipped to capitalize on this lead in terms of exporting goods and services where management/marketing skills and especially the availability of venture capital play a dominant role. The need for incentives to further capital formulation is therefore essential. The larger firm is in a better position to play this "follow up" game, but is less likely to innovate because of its heavy investment in existing equipment, processes and product patterns.

4. Some U. S. R&D activity is indeed moving abroad, and the trend is likely to increase. Government actions could slow the process but would not stop it. The transfer is desirable from many points of view, and inevitable, but steps must be taken to minimize its negative effects on the U. S. economy.

5. R&D investments can be increased by direct government funding of long-range mission-oriented research, and by tax policies directed toward the encouragement of private-sector support. The many other obstacles to the maintenance of U. S. leadership are addressed at length in the body of this document.

6. Foreign investment in U. S. firms, while increasing rapidly, is at present only a minor factor in the erosion of our technological lead. The resulting transfer of technology need not be harmful if we ourselves act promptly and positively to capture and protect potential markets. However the extent of such investment needs to be monitored and, if necessary, controlled by a central authority.

7. Again, U. S. exports of technology and high technology products are not necessarily detrimental to our international stature. A two-way flow, and a coherent national policy, are essential to our well-being. On the other hand, it should be noted that our society is becoming service/information oriented. The sale of knowledge must be placed on a business basis.

8. Licensing and joint ventures abroad can be beneficial to the U. S. if we can maintain the two-way flow of technological innovation. Potential exports are being lost due to the export of technology, but this need not be the case with careful planning at the national level.

9. Our recommendations for improving export performance in high technology goods and services are given at the end of this document. It is our contention that this needs to be considered as an intrinsic component of a total technology policy which recognizes the need for balance and negotiation at an international level.

1. <u>The Role of the Institute of Electrical and Electronics Engineers</u>

On behalf of this Institute, usually referred to as IEEE, I wish to express my appreciation for the opportunity to present our viewpoint on the matters being considered by this Joint Committee. The IEEE is well-qualified to address these issues. This organization has as its origin the incorporation in New York State in 1884 of the American Institute of Electrical Engineers, which merged with the Institute of Radio Engineers in 1961 to form the Institute of Electrical and Electronics Engineers. The aim of the original organization was "to advance the art and science of Electrical Engineering" by all appropriate acts and activities. In its 96 years of existence the membership has grown from 46 to over 185,000, and its scope has continuously expanded as a unique leader in its field and a major institution in the field of engineering on both the domestic and the international scene. Its members cover the entire spectrum of associated interests, including teaching, research, government and industry, private individuals, small business, and mammoth multinational enterprises. We are deeply involved in the high technology areas of electro-science, from aircraft electronics through computers, lasers and microwave repeaters to satellite communications.

Our role in the current investigation is to try to point out the complexity, diversity and interrelationships of the factors which must be considered. We cannot propose a solution to all the related problems; we do believe that we have a contribution to make in terms of clarifying the issues, presenting the legitimate concerns of the affected parties, and making recommendations (in Section 10) for a phased program of investigation and supportive actions which will enhance understanding of the relationships between research, technology, and economic growth, and assist in the definition of the appropriate role of Government in improving the international technological and economic standing of the United States.

2. Background

The typical pattern of Research and Development in the United States has changed radically since the time of the inventor working independently in a laboratory in his own home. At the start of World War I, the American Chemical Society offered to help President Wilson in any areas of chemistry or chemical engineering, to which his response was "Thank you very much for the offer, but we already have a chemical engineer working at Edgewood Arsenal." In contrast, we now have a formalized team structure to attack almost all aspects of R&D.

The U. S. has not in the past always been a leader in Science and Technology, but rather an "early adaptor" of R&D performed typically in Europe. We have made progress in the "four Is": generation of breakthrough ideas, and application and development phases - invention, innovation and imitation (or diffusion) - and as recently as 5 years ago it appeared that the U. S. had achieved and was likely to retain the position of world leader.* However, we are now in the process of letting this advantage slip away.

Measures of international stature are difficult to quantify, but we can get a general idea in the realm of science by looking at indicators such as the citizenship of Nobel prize winners for Science. Table 1 shows the improvement in relative standing of the U. S. since the beginning of the century, moving up from fifth place prior to 1930, and subsequently maintaining a significant lead over other nations, until in the most recent

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*Cetron, M. J., "Technology Transfer: Where We Stand Today"; Technology Transfer (Eds.; Davidson, Cetron & Goldhar), NATO Advanced Study Institute Science; Noordhoff; (Leyden) 1974; pp. 1-28.

Table 1

Nobel Prize Awards, by Country, 1901-1977

1901-1930		1931-1960		1961-1977	
Germany	27	United States	33	United States	53
England	15	England	18	England	20
France	11	Germany	14	Germany	6
Sweden	6	Switzerland	5	France	5
United States	6	Austria	4	Sweden	4
Holland	6	Sweden	2	USSR	3
Denmark	4	Italy	2	Austria	2
Austria	3	USSR	2	Belgium	2
				Denmark	2
				Argentina	1
				Australia	1
				Canada	1
				Italy	1
				Norway	1

Table 2

Selected Invention and Patent Rates, by Country*

	A Total Inventions on Selected List 1600-Present	B Average Annual Patenting Rate - 1930-1939	C** Annual Patenting Rate - 1975
United States	203	38,300	56,509
Great Britain	58	9,050	12,322
Germany	32	14,600	37,733#
France	29	9,550	13,386
Italy	14	3,900	--
Switzerland	--	3,130	4,369
Sweden	4	1,030	9,100##

*Bode, H., Basic Research and National Goals, (Washington, D. C.: National Academy of Sciences, March 1965).

**Private Communication, U. S. Department of Commerce, Patent and Trademark Office, May 1978.

#West Germany only (FRG).

##This is made up of 7,233 foreign filings, and only 1867 by Swedish nationals.

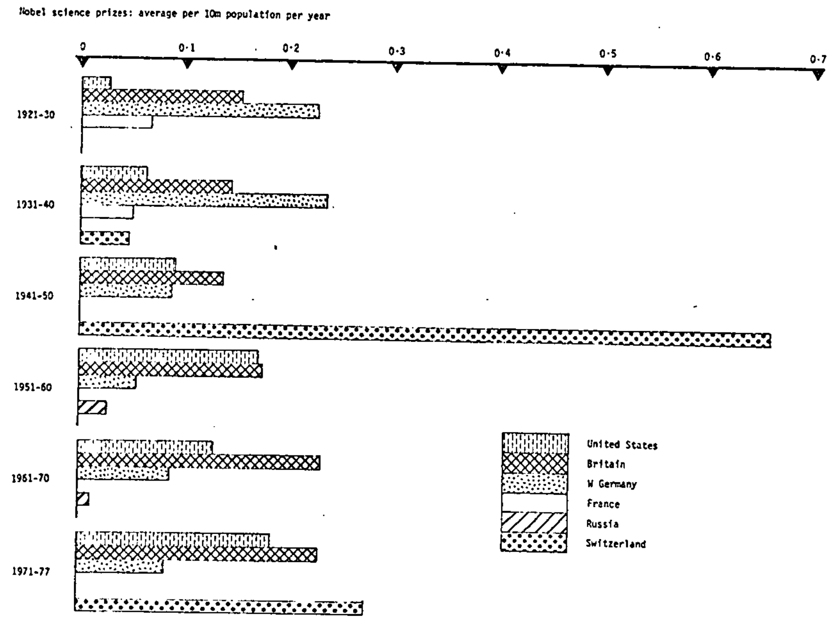
list the U. S. has more than all others combined. This rather sudden acceleration may be attributed in part to the substantial influx of scientists who were educated abroad and migrated to the U. S. because of the political or religious turmoil of the 1930s. It is also a result of the great material resources which are available in the U. S. The scientific areas where we lead are those which require expensive experimental equipment, which some nations cannot provide. (However these are not necessarily areas which can be readily commercialized.) Even here, however, if we examine the number of Nobel prizes as a function of population (Figure 1), the United States -- although still a leader -- no longer dominates as it did prior to 1950.

In the realm of technology, the U. S. has been pre-eminent over a much longer period. Two crude measures of comparative standing are shown in Table 2. Column A indicates by nationality the number of authors of major inventions from Colonial times to the present day. Such a tabulation can be regarded as distorted both by chauvinism in the selection of responsible individuals, and lack of discrimination in the choice of inventions. The remaining columns show the average patenting rate in the 1930s and in 1975, for the countries listed. By either criterion, the U. S. was ahead of other nations; however, this position of leadership has been eroded over the last decade, as shown in Figure 2. In a recent report,* OECD states that except for the computer, aerospace, and heavy electronics industries, technology is primarily transferred into the United States from other

*Gaps in Technology, (Paris, France: Organization for Economic Cooperation and Development, 1970).

Figure 1

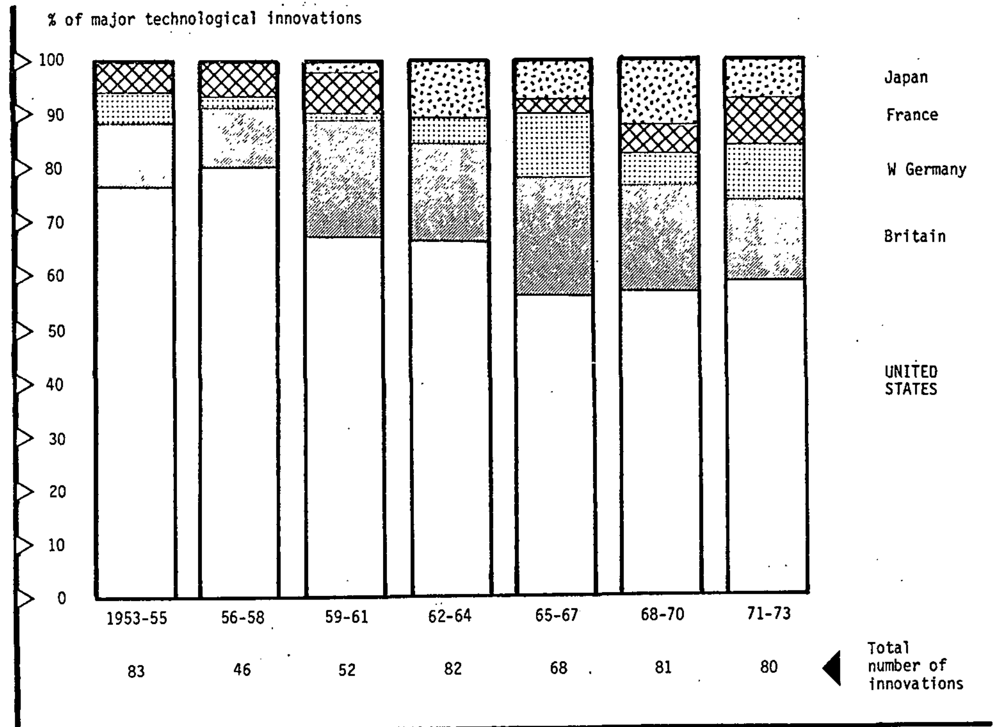
NOBEL SCIENCE PRIZES: AVERAGE PER 10 M POPULATION PER YEAR



Source: National Science Foundation, Science Indicators, as depicted in "The Science of Olympics", Business Brief, The Economist, May 20, 1978, pp. 86, 87.

Figure 2

PERCENTAGE OF MAJOR TECHNICAL INNOVATIONS



Source: National Science Foundation Indicators, as depicted in "The Science Olympics", Business Brief, The Economist, May 20, 1978, pp. 86, 87.

countries. In the four high technology industries, aerospace, heavy electronics (including computers), chemicals and pharmaceuticals, the two areas where we lead are aerospace and electronics, where significant amounts of monies are funneled through government agencies by the Department of Defense, NASA, HEW, Department of Energy, etc. In the other two industries, chemistry and pharmaceuticals, since they are mature technological industries the bulk of their money comes from internal corporate funds or the stock market. This provides some indication that when the government funnels R&D money to private firms (as in electronics and aerospace), the industry prospers and we have a technological lead.

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3. The Importance of Technology

Both technology and technology-based products are of major significance to the U. S. in terms of international trade as well as in generating jobs and products for domestic consumption. The export of technology, as distinct from the export of products, brings revenues to U. S. companies, and thus to the U. S. economy, in the form of license fees and royalties. In 1977 the gross income from such sources was $2.95 billion, compared to $.66 billion in 1965. The net income (technology export minus technology import, neglecting products) for 1977 was $2.67 billion, comparable in magnitude to the $3.25 billion U. S. trade surplus for all manufactured goods.[*]

The total contribution of technology to our economic welfare however cannot be measured solely in terms of trade balance. The tremendous increase in productivity of U. S. industry over the past thirty years can be attributed primarily to the application and utilization of technological advances. Between 1947 and 1965, the average annual increase in output per man in private industry ranged from 2% to 6%, the greatest change being in the communications and utility sector,[**] where the growth in real output reached 7.5% p.a. by 1970. Advances in productivity are responsible for a large part of economic progress, in terms of GNP per capita, and these trends are expected to continue through 1990.[***] One of the most important weapons in our arsenal against inflation is such increased productivity, which can be achieved through improved technologies and innovations.

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[*] Langan, Patricia, "Those Worrisome Technology Exports", Fortune, May 22, 1978. These data are confirmed by the latest figures provided by the U. S. Department of Commerce (Private Communication), excluding the category of management and services.

[**] Private communication from the National Bureau of Economic Research.

[***] The Conference Board, "The U. S. Economy in 1990", in A Look at Business in 1990, White House Conference on the Industrial World Ahead, Washington, D. C., 1972.

However, the direct economic gains on the international scene resulting from the sale of technology-based products have been declining rapidly. In the area of semi-conductor electronics, where U. S. corporations have made nearly every technological breakthrough, the U. S. trade balance has been negative since 1968, and now stands at minus $2 billion, excluding only one category -- that of computers -- in which the U. S. retains a favorable balance.* Further comments concerning this particular situation will be made below, in section 6. An OECD report** cites the computer industry as one of only three areas in which the U. S. retains its technological lead, in terms of net export of the technology base. (The other two are aerospace and heavy electronics.)

Other studies have confirmed that the competitive strength of U. S. manufacturing industries in world markets is closely correlated with the performance in technological innovation.*** However, with regard to particular products, technological leads only temporarily provide comparative advantages, for the duration of the so-called imitation lag.****

In the following section, therefore, we will examine the characteristics of technology and its evolution, to assist in determining an optimum policy in controlling and/or capitalizing upon its development, application and dissemination.

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*Boretsky, Michael, U. S. Department of Commerce, as quoted in Fortune, May 22, 1978, p. 108.

**Gaps in Technology, Organization for Economic Cooperation and Development, 1970.

***See for example: Vernon, R., "International Investment and International Trade in the Product Cycle". In: Quarterly Journal of Economics, Vol. 80 (1966); Keesing, D. B., "The Impact of Research and Development on United States Trade". In: Journal of Political Economy, Vol. 75 (1967); Baldwin, R. E., "Determinants of the Commodity Structure of U. S. Trade". In: American Economic Review, Vol. 61 (1971).

****Posner, M. V., "International Trade and Technical Change". In: Oxford Economic Papers, Vol. 13 (1961).

4. The Characteristics of Technology

The most obvious characteristic of technology in general is that it changes; old products and procedures are replaced by new. This is a continuing process, so that at any given time and place the technology being practiced covers a spectrum from the old and stable to the new and rapidly changing. The impetus towards newer technology is a consequence of its potential to increase the productivity of a society's stock of resources. Solow* estimates that over the past century, 80% of the growth in the U. S. economy has resulted from advances in technology. The remaining 20% has been due to increases in the amount of resources.

In general, the increase in productivity is more rapid when the technology is new, and it thus yields greater returns to society than does a mature technology. There may be argument as to the distribution of these returns -- the major profit almost never accrues to the original innovator -- but there is general agreement that all members of the society benefit.

The growth of a new technology follows the familiar S-shaped curve as shown in Figure 3. An incipient period of rapid technological change -- "leading edge" technology -- is followed by a period of high growth but less change, manifested by increasing standardization. This is succeeded by a "mature" period of relatively slow change and slowing growth, and maximum return on the investment. Because of this growth pattern, the bulk

*Solow, R., "Technical Change and the Aggregate Production Function", in Review of Economics and Statistics, August 1957.

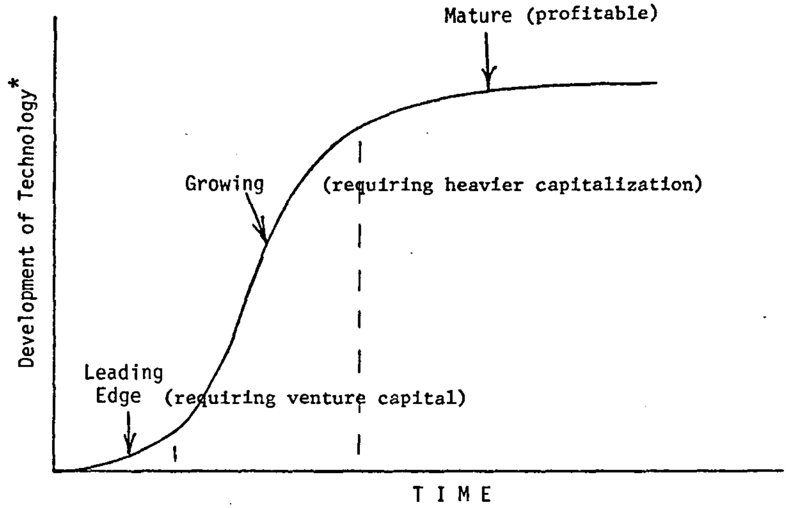

Figure 3. Technology Growth Curve

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*A typical measure is the percentage of firms in a particular product area which adopt the new technology.

of a technology being practiced is relatively mature and approaching stability.* If a new technology were to disappear in its incipient stage -- as many do -- it would hardly be noticed in aggregate statistics. However, the industry and the nation alike suffer when this happens, since it is the subsequent stages which provide substantial economic rewards.

Once a technology has been firmly established, and incorporated in a product or set of products, the frontier -- the place "where the action is" -- shifts from science and engineering to production and marketing. Instead of concentrating on making a single item work, the company concerned must learn to produce in quantity: to make the same item every time, and optimize the work flow. Customers must be acquired, and shown how to use the product. Service men must be trained -- much of the rapid post-war growth of "hi-fi" and TV equipment sales was spurred on by the training of radar technicians in the military. Ultimately the major benefits of a new technology accrue <u>not</u> to the technological innovator, but to those who solve the production and marketing problems.

Not only does the technology <u>change</u> over time, but it <u>moves</u>, and cannot be confined. Those whose command of a technology permits them to enjoy a position of monopoly have always tried to keep this advantage to themselves. Such attempts have invariably failed, and are doomed to failure by the very nature of things. The sale of any product embodying the technology necessarily reveals the most important item of information -- that the technology is possible. The processes of technical marketing also provide other data, and the more complex the product, the more information must be disseminated (concerning application and maintenance).

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*However, in order to ensure continued national economic health, a portion of the profits from a mature technology must be reinvested in new and efficient research and development; otherwise the technology well will run dry.

The need to provide acceptable technical service requires that the local market supplier must understand the operation of the product, its virtues and limitations, and extends beyond this to require knowledge of the design and fabrication of the product as well as its mode of functioning such that one is able to diagnose field difficulties and make the requisite repairs or modifications.*

The transfer of technology and of intellectual property is perhaps accomplished most readily through the mobility of people. This process occurs not only through hiring practices deliberately designed to acquire advance technological information, but through the routine day-to-day mobility of the work force within and between companies, industries and nations.

It is of course undeniable that technology transfer is facilitated by foreign assembly, foreign manufacture of components, and complete foreign manufacture. But it is essential to understand that the absence of these may have other negative effects for the industry involved, including both the loss of foreign markets and the creation of new sources of foreign competition, and even so will not result in protection of the basic technology. The dissemination of technology cannot be stopped: it can only be controlled and slowed down.**

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*Steele, Lowell W., The Economics of International Technology Transfer, in Karl A. Stroetmann (Ed.) Innovation, Economic Change and Technology Policies, Bonn, Germany, 1976.

**How Technology Transfer Affects the Competitive Position of the U. S. in the World Aviation Market (Arlington, Va.: Forecasting International, Ltd., March 3, 1972).

5. National Technological Strategy Options

There is more than one attractive strategy in playing the "technology game" on the international scene, and by no means all of the advantages lie with the innovative leader. Before attempting to discuss policy options for the United States, we must consider the implications of "leader" and "follower" roles. The discussion which follows is based upon an excellent summary by Horn, of the Institut für Weltwirtschaft in Kiel.*

> Technological progress continuously creates new products. Therefore, technological leads and lags are a steady source of international trade. A country which is able to generate a higher rate of innovations than other countries will be able to permanently produce a greater proportion of new goods. Countries which are less capable of producing technological innovations will have to specialize in the production of traditional goods.
>
> This leads to the question of which factors determine international differences in the innovative activity of countries. The answer to this question is suggested by the so-called product life cycle approach to international trade.** Simplified, the product life cycle hypothesis can be described as follows: Products and processes of production typically pass through a cycle which is characterized by an increasing degree of standardization (maturation). The most advanced countries possess comparative advantages in the production

*Horn, Ernst-Jurgen, "International Trade and Technological Innovation: The German Position Vis-a-Vis Other Developed Market Economies", in Karl A. Stroetmann (Ed.) Innovation, Economic Change and Technology Policies, Bonn, Germany, 1976.

**Vernon, R., "International Investment and International Trade in the Product Cycle". In: Quarterly Journal of Economics, Vol. 80 (1966); and Hirsch, S., Location of Industry and International Competitiveness. Oxford: Clarendon Press, 1967, and Gruber, W. H., Mehta, D., Vernon, R., "The R&D Factor in International Trade and International Investment of United States Industries". In: Journal of Political Economy, Vol. 75 (1967), and Wells, L. T. Jr., "International Trade. The Product Life Cycle Approach". In: Idem (ed.), The Product Life Cycle and International Trade, Boston: Harvard University, 1972.

> of new technologies, e.g. in R&D, and in the production of goods during the early phases of the cycle. On the one hand, these countries are relatively abundantly endowed with skilled manpower which is intensively used in the above mentioned activities and whose availability determines whether these activities can or cannot take place. Furthermore, risk capital to finance R&D activities is relatively abundant. On the other hand, a high per capita income provides domestic markets capable of absorbing new products, e.g. new consumer goods, labour-saving household devices and new labour-saving investment goods. When products become more mature, highly qualified manpower becomes less critical and the other factors of production gain influence in determining comparative advantage. In the course of increasing maturation of products or processes of production the comparative advantage shifts to less advanced industrial countries which can already handle the technology in question and are able to compete successfully with the innovating country because they enjoy the advantage of lower wages.* In the late phases of the cycle when products are mature and standardized, comparative advantage shifts to the developing countries.

Even in the high technology phase, there are advantages in occupying second place, in that the high risks and inevitable "false steps" will be taken by the leader. A nation which can maintain a minimal gap** can then be prepared to buy the products of leading edge technology, but produce and sell slightly less advanced products where the margins are less, but the volume is much greater. For example, Japan buys avionics and sells color television.

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*Haitani, K., "Low Wages, Productive Efficiency, and Comparative Advantage". In: Kyklos, Vol. 24 (1971).

**See for example
Hufbauer, G.C., Synthetic Materials and the Theory of International Trade (Cambridge, Mass.: Harvard University Press, 1966)
and
Vernon, Raymond (Ed.), Big Business and the State (Cambridge, Mass.: Harvard University Press, 1974)

This option is open only to those nations/corporations whose technical level is similar to that of the innovator. The American Indian, for instance, could not imitate the settlers' firearms because he had no knowledge of the requisite skills in making and forming steel, casting lead, producing nitre, sulfur, etc. There are plentiful modern instances, also, where major problems have arisen due to disparities not only in a specific technology, but in the necessary supporting infrastructure and in a whole range of ancillary technologies.*

* See for example
Baranson, Jack, Industrial Technology Transfer by U.S. Firms to Overseas Affiliates Under Licensing Agreements: Policies, Practices and Conditioning Factors (Arlington, Va.: Forecasting International, Ltd., 1975)

6. The United States Posture

Whatever the relative economic advantages and disadvantages, it appears to be the consensus of both government and industry opinion that the U. S. should strive to retain technological leadership, and both interests are concerned that the U. S. is unduly eroding its position by exporting technology without adequate safeguards/recompense. The concern of governmental policy-makers is manifested by such meetings as this present hearing, under the joint auspices of the Senate Science, Technology and Space Subcommittee and the International Finance Subcommittee. Other aspects of the problem are being examined by a House Subcommittee, the Congressional Office of Technology Assessment, the National Security Council, the Office of Science and Technology Policy, the International Trade Commission, the National Science Foundation, and the departments of State, Defense, Treasury, Commerce and Labor. In view of the widespread interest, we are hopeful that the outcome will be a systematic program designed to establish U. S. priorities and to define a responsive approach for achieving identified objectives.

Industrial representatives are also very much aware that a review of our policies and practices regarding the creation and transfer of high technology is an urgent requirement. Foreign products incorporating technology acquired from the U. S. are beating out American productions in markets around the world -- including the U. S. itself. Because of this, U. S. manufacturers are harvesting too little of the return from their own innovations. Says J. Fred Bucy, President of Texas Instruments:* Today our toughest competition is coming from foreign companies whose ability to compete with us rests in part on their acquisition of U. S. technology... The time has come to stop selling our latest technologies, which are the most valuable things we've got." Horace D. McDonell, an executive vice president of Perkin-Elmer Corporation, sums it up more piquantly: "We want to sell more milk and fewer cows."**

Before we can evaluate the validity of this viewpoint, we wish to examine more closely the situation of the United States in the light of the technology flow pattern we have defined; given that our perception of our national role is that of a leader, what are our achievements relative to establishing, maintaining and capitalizing upon a technological lead?

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*An Analysis of Export Control of U. S. Technology: A DoD Perspective, Report of the Defense Science Board Task Force on Export of U. S. Technology, J. Fred Bucy, Jr., Chairman (Washington, D. C.: Office of the Director of Defense Research and Engineering, February 4, 1976).

**Langan, Patricia, op.cit.

7. The Current U. S. Status

There is no standard equation nor set of tables that can be employed to determine our current achievements in the application of technology to improving either the national well-being or the U. S. position in the export trade arena. Further, and probably of even greater importance, statistics that could be applied to examine this question are scattered and in some cases imperfect. However, we can begin to develop a feeling and in some cases gain both insights and indications by examining the information and data that are available. According to the product cycle hypothesis discussed in Section 5, innovative activities of countries depend on per capita income as a measure of the stage of the country in the development process. A study of 19 OECD member countries* showed a significant correlation between expenditure on research and development as a percentage of GNP, and per capita income. (At the level of the corporation, Mansfield** has demonstrated that a high level of research and development expenditure leads to increased productivity, and thence to improved gross profits, which permits and again tends to increase research and development funds. This relationship is depicted in Figure 4.) In response to this perceived relationship, both the U. S. and U. K. since 1945 have consistently spent over 2% of GNP on R&D.*** However, German expenditures increased from 1.4% of GNP in 1963 to 2.1% in 1971, whereas U. S. expenditure dropped

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*Horn, Ernst-Jurgen, op.cit.

**Mansfield, E., "Research and Development and Economic Growth/Productivity", National Science Foundation Colloquium (Washington, D. C.: GPO, 1971).

***"The Science Olympics", loc. cit.

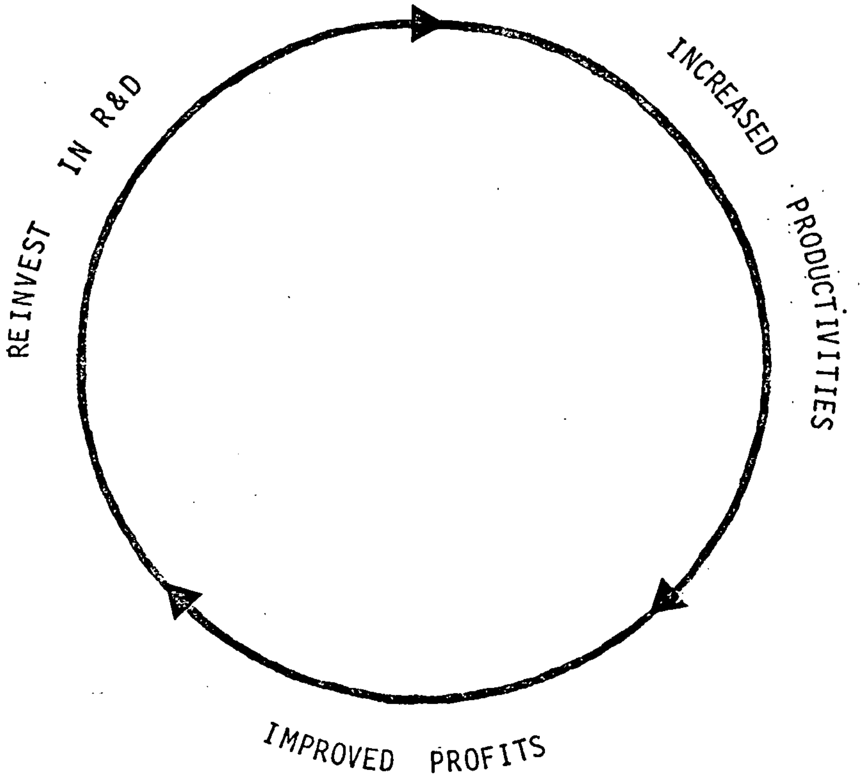

FIGURE 4. THE R&D CYCLE

from 3.3% GNP to 2.6%, and by 1976 was down to 2.2%. The U. S. figure also includes about 50% for defense-related R&D, which has limited "spill-over" to the commercial sector.

Gross expenditure on research and development (as a percentage of GNP) and gross research and development expenditure per capita also correlate highly with relative market share for research intensive products. Thus we can use research and development expenditures as a rough measure of performance in trade in research intensive products. In general, such studies as Horn's have shown research and development activity to be the most important determinant of the structural pattern of international competitiveness. The influence of the research and development variable in the U. S. appeared to be even stronger than in the case of Germany, with which it was compared.*

At the broadest level the relative position of the U. S. in the world export market between 1960 and 1976 is shown in Figure 5. During this period we can see that, in round terms, the U. S. share has dropped from 18% in 1960 to 12% in 1976, while that of the Federal Republic of Germany has moved slightly upward from 10% to 11% of the total world market. On the other hand we find that the Japanese have improved their position from 4% of the total market in 1960 to 7.5% in 1976, approximately doubling their total export share.

This figure includes not only products based upon high technology and mature technology but also the exporting of raw materials, etc. It is useful only for presenting a broad overview. Focusing upon manufactured

*U. S. Tariff Commission figures, and Horn, Ernst-Jurgen, op. cit.

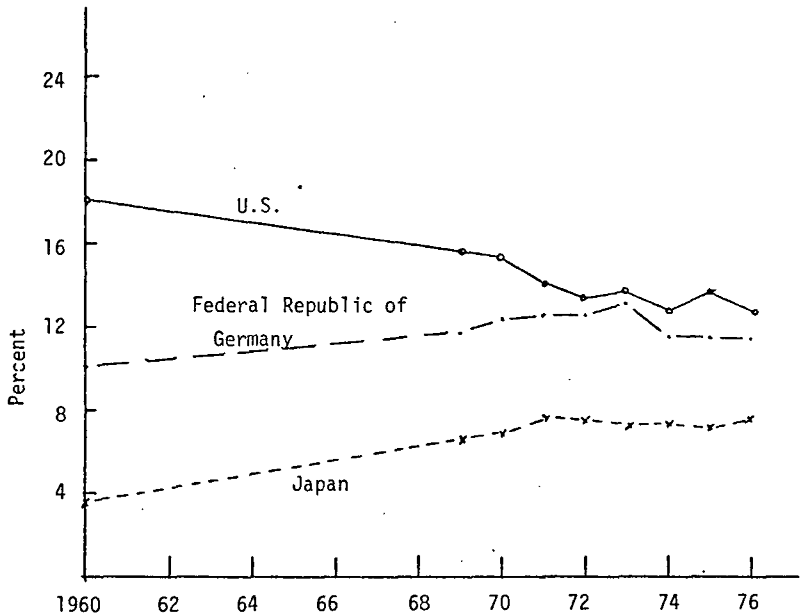

Figure 5. Share of the Total World Export Market (All products and raw materials)

goods, we see in Figure 6 that the United States' position in the world market has improved only slowly during the past five years. The position of the Federal Republic of Germany has remained relatively stable over this total period. On the other hand the Japanese have increased their portion of this export market from 6.5% in 1960 to 15% in 1978. The steady increase in Japan's export of manufactured products is significant and appears to be far more important than the previous penetration by Japan of the total export market. In particular, Japan's production of consumer electronics has increased by a factor of five over the past 10 years, and 62% of the 1976 output was exported ($4.8 billion),* 30% to the U. S.

Data become more difficult to obtain when we focus upon high technology and its impact upon exports and world trade. As shown in Figure 7, this is the only area in which the U. S. has not only maintained but increased its trade balance. A recent symposium** on "Innovation, Economic Change and Technology Policies" provides some insights in this area. This symposium, sponsored in part by the National Bureau of Standards, contains several presentations which provide some insights into the problem and possible solutions to that problem. Of particular note is a paper presented by Ernst-Jurgen Horn (pages 129-147), which was cited earlier.

Horn has developed a measure of the significance of high technology products upon the international competitiveness of nations. This measure,

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*"Japan's New Electronics Goodies", Business Brief, The Economist, April 22, 1978, pp. 84, 85.

**Stroetmann, Karl A. (Ed.) Innovation, Economic Change and Technology Policies (Bonn, Germany, 1976).

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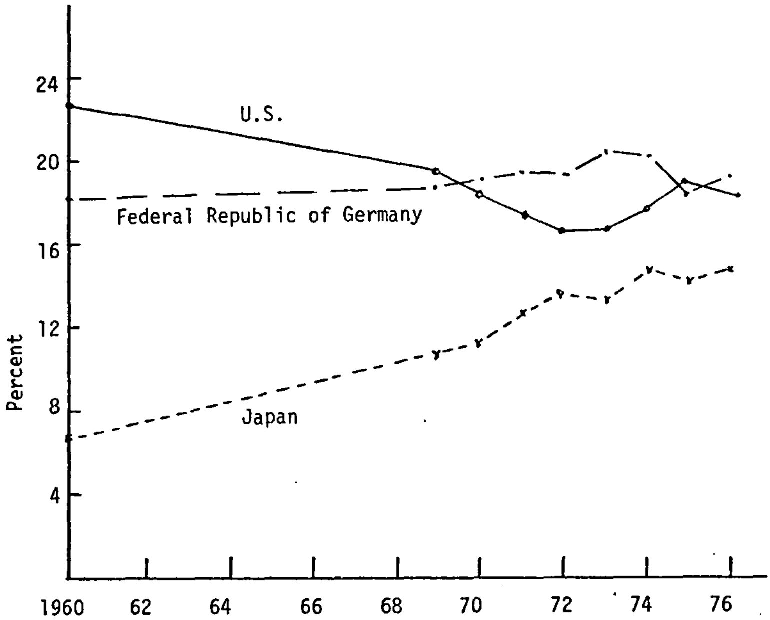
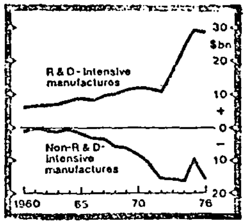


Figure 6. Share of the Total World Export Market (Manufactured Goods Only)

Figure 7

U. S. R&D TRADE BALANCE*



*(Exports less imports).

Source: National Science Foundation Indicators, as depicted in "The Science Olympics", Business Brief, The Economist, May 20, 1978, pp. 86, 87.

which he calls "revealed comparative advantage" (RCA)* provides insight into what is happening in the world arena concerning the international sale of high technology products.

Figure 8 shows RCA values for the United States, the Federal Republic of Germany and Japan for the periods 1963 through 1973 as well as a projection of these figures into the future. Note that the United States position has been eroding significantly, decreasing by about 30 units during the time period under examination; that the Federal Republic of Germany's position appears to have remained relatively constant although weakening somewhat; and that the Japanese position has improved, also by about 30 units. (In this figure a negative value means that they started at a disadvantage.) The cross-over between United States and Japan in this particular segment of the market would occur somewhere in the period 1980 through 1985, based upon extrapolation at the current rate of change.

A similar conclusion was presented in a document issued by the National Planning Association** in which a measure was defined of the lag*** between U. S. and Japanese technology, a graphic representation of which is shown in Figure 9. The relative lag impacts upon the future relative

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*This indicator measures the extent to which foreign trade surpluses (deficits) in one product group diverge from the trade position of this country in total manufactured goods. The measure has been normed so that it can assume values between + 100 and -100. High positive values of the measure indicate a high international competitiveness. For method of calculation the reader is referred to the article as cited, page 144 et seq.

**New International Realities, (National Planning Association, Washington, D. C., 1978).

***This is expressed in terms of the relative technological change over time: the rate of growth of output holding all inputs constant. For a precise definition of the measure, see Christensen, L. R., D. Cummings and D. W. Jorgenson, "Economic Growth, 1947-1973: An International Comparison," in J. W. Dendrick and B. Vaccara (Eds.), New Developments in Productivity Measurement, Studies in Income and Wealth, Vol. 41 (New York: Columbia University Press), forthcoming.

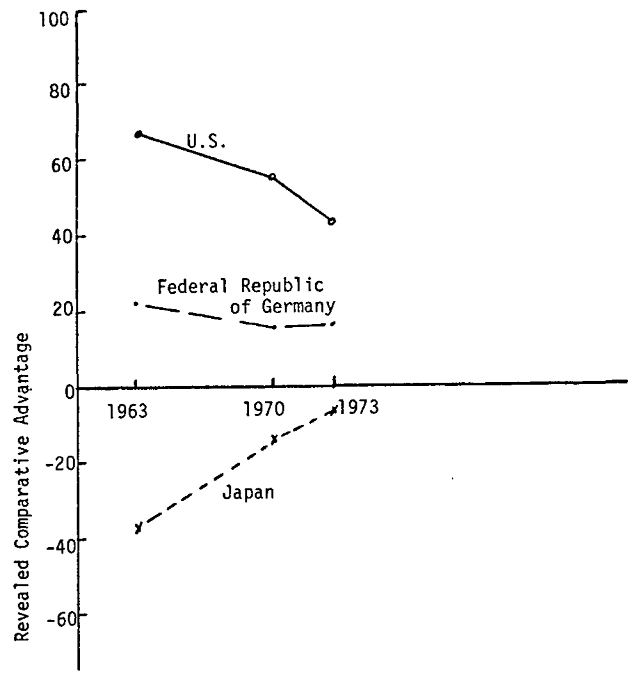

Figure 8. Revealed Comparative Advantage*
Versus Time, for the U.S., Federal Republic
Of Germany and Japan

*This indicator measures the extent to which foreign trade surpluses (deficits) in one product group diverge from the trade position of this country in total manufactured goods. The measure has been normed so that it can assume values between + 100 and -100. High positive values of the measure indicate a high international competitiveness. For method of calculation the reader is referred to:

Horn, Ernst-Jurgen, "International Trade and Technological Innovation: The German Position Vis-a-Vis Other Developed Market Economies", in Karl A. Stroetmann (Ed.) Innovation, Economic Change and Technology Policies, Bonn, Germany, 1976, page 144 et seq.

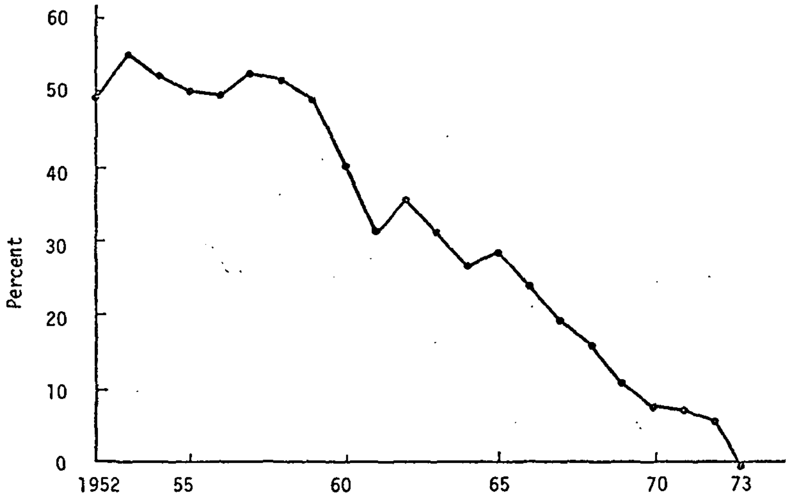

Figure 9. The U. S. - Japanese Technology Lag*

*This is expressed in terms of the relative technological change over time: the rate of growth of output holding all inputs constant. For a precise definition of the measure, see Christensen, L. R., D. Cummings and D. W. Jorgenson, "Economic Growth, 1947-1973: An International Comparison," in J. W. Dendrick and B. Vaccara (Eds.), New Developments in Productivity Measurement, Studies in Income and Wealth, Vol. 41 (New York: Columbia University Press), forthcoming.

trade balance. The significance of this closing of the gap confirms the data in Horn's article, and indicates that we will shortly be faced with a competitor who is technologically on a par with the United States.

This raises the question of where are specific U. S. industries in relation to high technology development or the generation of high technology products?

As previously noted, because of the area of interest of the IEEE, we are restricting our examination to three major segments of the U. S. industrial base in which we currently maintain a lead. These are electronics and electrical equipment in general, the computer field specifically, as well as the aircraft industry.

In the broadest sense we must examine the inputs to the high technology segment of industry, by looking at the research and development expenditures as a percentage of the GNP (see Figure 10) as well as the number of scientists and engineers employed in the research and development areas, which is portrayed in Figure 11. Note that both of these Figures include the area of defense-related R&D, and this fact must be borne in mind in their interpretation. Half the total government outlay for R&D in the U. S. is related to defense, whereas the comparable figures for FRG and Japan are 11% and 2% respectively. The commercial emphasis in both Japan and Germany is paying off. These countries have led a huge increase in the number of foreign inventions being patented in the U. S.,* and by the addition of

*Technology Assessment and Forecast, 7th Report (Washington, D. C.: U. S. Department of Commerce Patent and Trademark Office, March 1977).

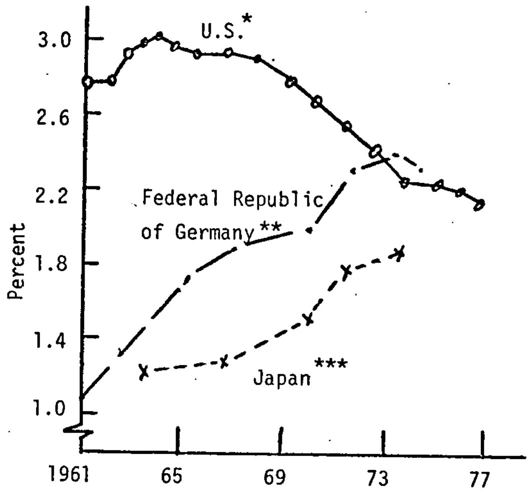

Figure 10. R & D Expenditures as a
Percentage of National GNP

*This includes about 50% defense-related R&D, most of which cannot be adopted to commercialization.

**This includes about 11% defense-related R&D.

***This includes about 2% defense-realated R&D.

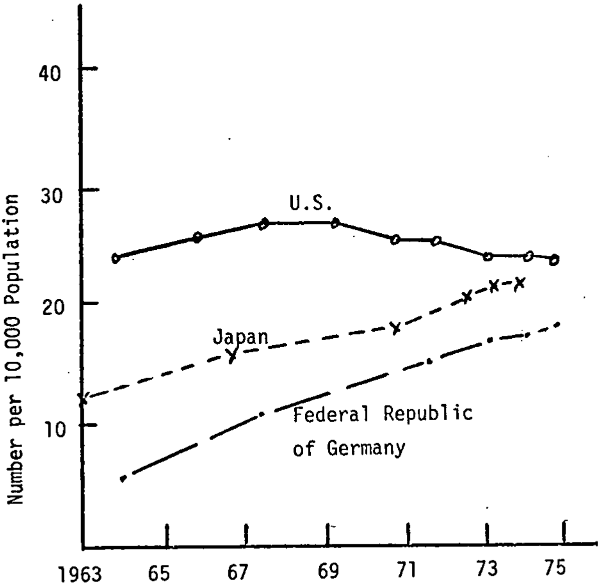

Figure 11. Scientists and Engineers Engaged in Research and Development

"technical wizardry" are expanding their share of U. S. and world markets in those less technologically exciting goods which make up the bulk of world trade.*

The rationale for examining the high technology manufactured goods is based upon material previously generated for the U. S. Senate Committee on Finance.** Data were presented which indicated that high technology industries (that is, product industries whose products depend upon the application of high technology) provided for the U. S. a significant positive balance of trade as opposed to the lower technology manufactured goods or raw materials. This was previously shown also in Figure 7. A reproduction of the table for the period 1960 through 1971 is shown in Table 3. The specific industries categorized as high technology, medium technology and low technology are listed in Table 4 for reference, ranked in decreasing order of R&D investment as a percentage of shipments (1966 data)***

To bring the problem into focus, let us look at specific examples, as previously: in the semi-conductor industry the lead clearly has been with the United States for many years; the development of transistors, integrated circuits, etc. has placed the United States in a very strong position in this particular area. However, starting in about 1965 several developments occurred which ultimately must have serious consequences upon the balance of trade for the United States in this area. First, these semi-conductor

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*"The Science Olympics", loc.cit.

**<u>Implications of Multinational Firms for World Trade and Investment and for U. S. Trade and Labor</u> (Committee on Finance, U. S. Senate, February 1973).

***Based on <u>U. S. Census of Manufactures.</u>

	Contribution in Billions of Current Dollars			
	1960	1965	1970	1971
High technology manufactured goods	+6.6	+9.1	+9.6	+8.3
Agricultural products	+1.0	+2.1	+1.5	+1.9
Low technology manufactured goods	-0.9	-2.9	-6.2	-8.3
Raw materials	-1.7	-2.8	-2.5	-4.1

Table 3. Contribution to the U.S. Balance of Payments by Industrial Segments

High Technology Industries

Electrical machinery and apparatus, incl. household appliances----------------
Drugs------------------------------------
Industrial chemicals--------------------
Instruments-----------------------------
Transportation equipment----------------
Radio, T.V., electronic components---------
Farm machinery and equipment--------------
Electronic computing equipment and miscellaneous nonelectrical machinery----
Office machines--------------------------

Medium Technology Industries

Soaps and cosmetics-----------------------
Rubber products---------------------------
Industrial machinery and equipment---------
Miscellaneous chemicals not included elsewhere----------------------------
Stone, clay, and glass products-----------
Primary and fabricated aluminum, plus misc. metal products--------------------
Fabricated metals (excl. aluminum, copper, and brass)--------------------------
Miscellaneous electrical machinery not included elsewhere---------------------
Grain mill products-----------------------
Plastics-----------------------------------

Low Technology Industries

Primary metals (excl. aluminum)------------
Paper and allied products-----------------
Miscellaneous manufacturing (incl. ordnance, leather, and tobacco)------------------
Lumber, wood products, and furniture-------
Miscellaneous food products (excl. grain mills)----------------------------------
Printing and publishing--------------------
Textiles and apparel-----------------------

Table 4. Composition of Industrial Segments

companies begin to establish overseas operations. This is shown in Figure 12 which shows the number of firms who established overseas operations. Note that this number moved very rapidly from approximately 15 or 20 in 1966, to almost 100 in 1971. Further, we can examine the actual investment in overseas assembly facilities by the same semi-conductor industry. In Figure 13 we see the number of firms as a percentage of the total who established overseas assembly facilities. Starting in 1963 a very rapid development began of new overseas assembly plants by the semi-conductor industry, which reached a level of approximately 80% in 1972. Thus, most assembly or a significant portion of the assembly of semi-conductor products is currently being performed overseas by subsidiaries and joint ventures of U. S. semi-conductor organizations.

Several counterbalancing consequences of this action can be identified. On the positive side, the establishment of overseas production facilities has in several cases preempted the establishment of Japanese semi-conductor companies of production facilities in the area, and has also given the U. S. semi-conductor industry a local sales advantage. A second positive effect -- resulting from one of the probable primary reasons for the overseas movement, the availability of a large, semi-skilled labor force -- was the containment of total costs, resulting in consumer prices lower than could be achieved with U. S. production.

On the other side of the ledger, we must note the loss of employment opportunities here in the U. S. (at least in the short run) and the loss of national income (in the longer run) due to:

a. diversion of profits and tax income, and

b. establishment of potential competitive capability (through the transfer of the technology).

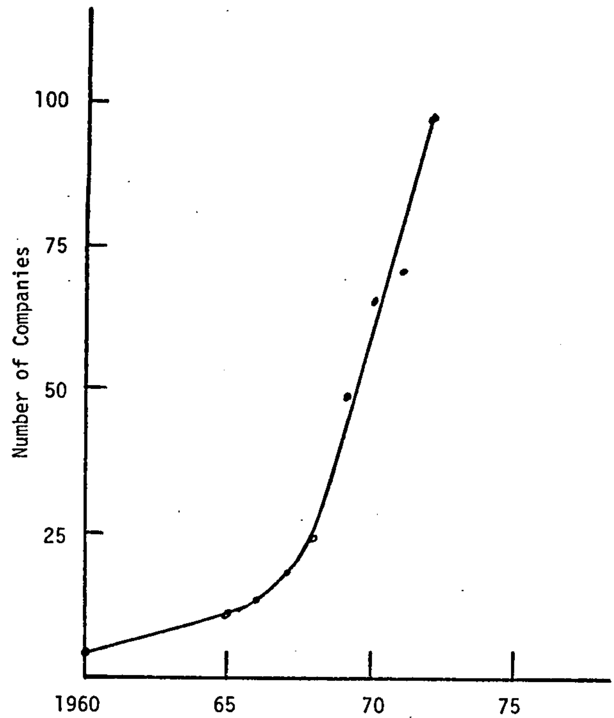

Figure 12. Number of U.S. Semiconductor Firms Establishing Overseas Operations

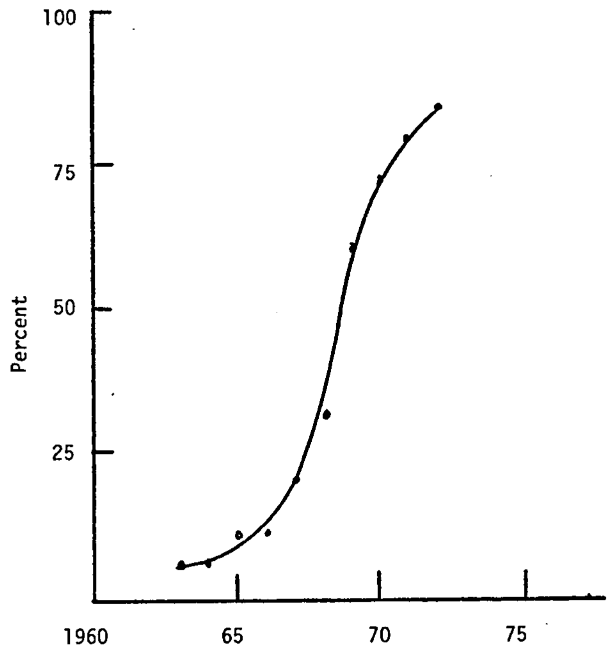

Figure 13. Cumulative Percentage of U.S. Semiconductor Companies Employing Off-Shore Assembly Facilities

The implication of the long term effects focuses the need for our industrial structure to maintain a technological lead in the semi-conductor area. This means that we must encourage innovation and the application of leading-edge technology at an ever increasing rate.

The Institute recognizes the importance of this issue and the complexities involved in trying to evaluate the variety of impacts. To attack this problem, the IEEE is in the process of convening a study group which will bring together industrial, governmental and academic experts who will examine the causes, modes and consequences of the transfer of high technology from the U. S. to foreign sites. This task force will examine, to the extent possible, the technical, economic and socio-political aspects of these and related issues.

In the context of the present discussion, let us now examine the question of what is the relationship between funding of research and development and high technology, and the product output by that industry. To do that we will examine the computer industry where some statistics are available; this may give us some insight into at least one segment of the total high technology area.

In examining the research and development investment as a percentage of the total revenue of five major organizations in the computer industry, we produced the results shown in Figure 14. It is interesting to note that the National Cash Register (NCR) Company as well as Burroughs maintained a relatively stable input of research and development dollars as a percentage of their revenue over significant periods of time. On the other hand IBM increased its percentage of research and development from approximately 4% in the late 1950s to nearly 7% in the period 1970 through 1974.

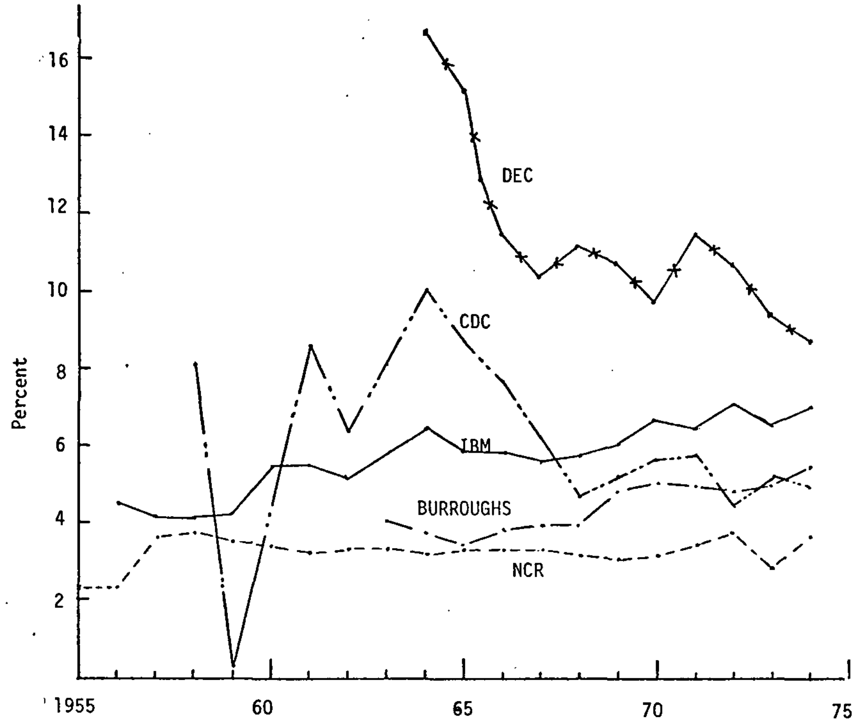

Figure 14. Computer Company R & D Investment as a Percentage of Revenue

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The two remaining companies examined were CDC and the Digital Equipment Corporation. CDC shows a sporadic fluctuation in its research and development investment, particularly during the time period 1958 through 1964. From that period on it began to decrease its research and development investment although it was not until 1967 that the percentage dropped below the IBM level.

During the time period 1958 through 1967 CDC was applying high technology to its product line and developing very rapid penetration of the market for various new devices and systems which were produced.

DEC was utilizing approximately 16.6% of its revenues for research and development investment in 1964 and 15.2% in 1965. This appears to be decreasing asymptotically. However, during the time period when DEC was investing significant amounts of money in the research and development effort it was a recognized leader in developing mini-computers and micro-computers for sale in the United States. This penetration was successful and it is today one of the leading organizations in that particular sub-area of computers and computer applications.

Figure 15 provides additional information as to the impact of research and development upon the growth and viability of various organizations which can be classified as high technology, innovative and mature. In this figure we have presented the average annual growth of these three groups of organizations or companies. The specific growth rates spanned the time frame 1969 through 1974.

Another issue which relates to the questions posed by the Subcommittees concerns company size. Without external support, only large organizations can afford the huge research investments needed to practice innovation in

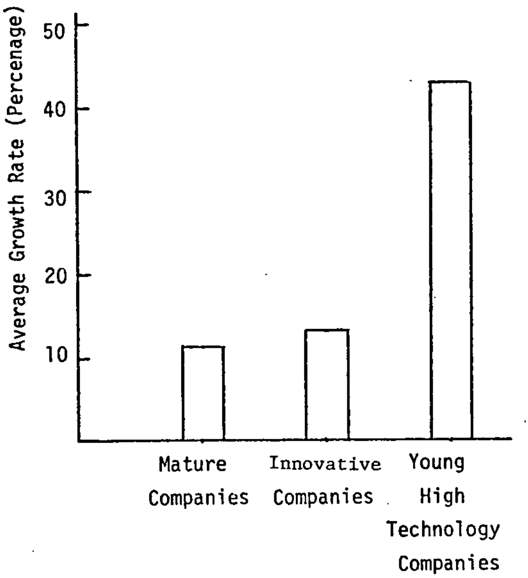

Figure 15. Comparison of Several Typical Companies - Annual Average Growth Versus Technological Classification From 1969 through 1977

specialized high technology areas. Yet in the U. S., businesses with fewer than 1000 employees produce 17 times as many major innovations per research dollar, while "medium-size" companies appear to be about 4 times as innovative.* Organizations such as Bell and IBM register a patent a day throughout the year, but are often either too inflexible to exploit innovations, or are inhibited from doing so by Federal regulations.

*"The Science Olympics", op.cit.

8. Problem Summary

Let us examine the problem from a different standpoint -- what are the effects of the lack of adequate funding? Several examples and some quotations from competitive nations may help to place in proper focus the more important aspects of the subject.

Some consequences of the lack of available research funds within the U. S. will serve as typical case-studies. The first of these involved Dr. Amdahl, a computer research scientist who worked for IBM, having design responsibilities for IBM models 704, 709 and 7030, and who managed the architectural planning of IBM System 360. Amdahl left IBM in order to pursue a proposed design of a future large scale system, which would have involved a radical change from IBM's then "present generation" computers.

Since Dr. Amdahl believed he had a technological idea whose time had come, he established his own firm in 1970 and when sufficient financing was not available from American firms, or venture capital sources, he proceeded to negotiate financing from a Japanese Company, Fujitsu, which now owns 28% of the stock. Some domestic support was provided by a Chicago business development firm, Heizer Corporation, which owns 23%. The Board of Directors controls 8%. First revenues were recorded in late 1975 for the 470 V/6 computer which competes with the larger, faster IBM System 370's. By 1977, Amdahl announced a net income after taxes of $27 million, on a turnover of $189 million -- a better profit rate than that shown by the industry as a whole.* The need for foreign financing effectively transferred

*"Europe's Chance of a Computer Revolution", Business International, The Economist, April 22, 1979, pp. 105, 106.

our large high speed computer system design technology not just to Fujitsu, but to Japan, because of the national solidarity of outlook. Japan has an integrated national policy designed to support its role as a modern industrial leader, and administered by MITI, the Ministry of International Trade and Industry. Because of this philosophy, there is no clear distinction between one firm and "Japan Inc." as far as relations with other nations are concerned.*

A second example is the LITEX light bulb case, where the inventor, Don Hollister, could not find funding for his new energy-conserving light bulb. The major U. S. manufacturers of light bulbs apparently were not interested in breaking down their production lines in their plants and starting a competitive business. Since venture capital was not available, in this instance the government intervened. ERDA (now the Department of Energy) agreed to underwrite the research and development costs ($310,000). The Government owns the patent, but Hollister has free licensing and use rights provided he exercises them. Otherwise, the patent lapses (similar to provisions of the Thornton Bill**) and the patent enters the public domain.

The third example is more general. It concerns the U. S. aircraft industry and its competitive position in the world market.***

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*See e.g. Oshima, Keichi, "Technology Transfer in Japan", in Cetron, M. J., H. F. Davidson and J. D. Goldhar (Eds.) Technology Transfer (Leiden, The Netherlands: Noordhoff, 1974).

**HR 6249 (95th Congress, First Session, 1977).

***A Study of How Technology Transfer Affects the Competitive Position of the United States in the World Aviation Market; Forecasting International, Ltd., Arlington, Va.; 1972; and A Study of the Key Aspects of Foreign Civil Aviation Competition; Forecasting International, Ltd., Arlington, Va.; 1976.

> In the past (since 1925) the United States has contributed most of the significant technological advances in the field. Although 22% of the ideas for advances originated in Europe, less than 5% were implemented by European countries first. Clearly, the U. S. is very efficient at taking a working prototype and incorporating it into an actual flying component for military and commercial use. It is in making the transition from a model to a successful in-service system that the U. S. is particularly capable.

In order for a country to adapt a technology developed elsewhere, the process of technology transfer is of infinite importance. It is a well-known fact that the acceptance, production and utilization of an advancement is often delayed for long periods of time after the initial development of that advancement. The effects of the U. S. ability rapidly to apply these technical advances has contributed significantly to increases in performance capability of U. S. aircraft. In the past this has resulted in an increasingly advantageous market position for the United States.

The cancellations of both the SST and B-1 efforts have contributed to an erosion of our previous position. The recent sale of the French A-300's (AIRBUS) to Eastern Airlines indicates that the American aircraft industry may be on the verge of losing its monopoly here in the States in the medium haul aircraft area.

> U.S. aerospace firms are forming joint ventures with foreign countries. Boeing will join with Japan on a $600 million venture to build a small (150-200 passenger) wide-bodied, low-noise, short takeoff airbus for use on domestic Japanese routes. The General Electric Co. has joined forces with SNECMA, owned by the French government, to produce the CFM 56 aircraft engine for use in STOL aircraft. Pratt & Whitney will join forces with a German consortium, MTU, and an Italian group formed by Fiat and Alfa Romeo to produce the JTIOD, a competitive engine. These engines will compete to power the next generation of commercial aircraft replacing the Boeing 727 and 737 and the McDonnell-Douglas

DC-9. Other competition in this category is Britain's Rolls-Royce which is trying to put together an engine consortium with French, German, Swedish, Italian and Belgian manufacturers.*

The penetration of the American makret can take several forms. Not only can the foreign organization sell to American firms, it can invest and obtain access to the technology via that approach. A very insightful analysis of this area was published in 1971 by Business International S.A.** In that report, the author examines the value to the European organization of investing in the U. S.

> The biggest reason for the greatly expanded and expanding European corporate investment in the U. S. lies in the attractions of the market -- its size, its profitability, its research and development stream, its new products and industries, its new process development and applications engineering. As one group of observers have put it as regards the office equipment, electronic components, and computer industries: "Operating on the American market is no longer the natural consequence of success on other markets, but a precondition of success on the world market."
>
> Manufacturing in the U. S. brings far quicker and far closer access to the innovative stimuli of the U. S. business environment. The U. S. has played the role of technological and marketing bellwether for Europe and the world throughout the postwar era. True, the U. S. has no monopoly on invention or discovery of new products and processes. However, of 110 postwar first commercial introductions ("innovations") qualified as "significant" by the OECD***, 74 were first commercialized in the U. S. and practically all 74 were first marketed by U. S.-owned firms.

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*Cetron, M. J. and James L. Duda; "International Technology Transfer in One Industry - Aircraft", in Cetron, M. J., H. F. Davidson and J. D. Goldhar (Eds.) Technology Transfer (Leiden, The Netherlands: Noordhoff, 1974).

**"European Business Strategies in the United States"; Business International S.A., Geneva, Switzerland; 1971.

***Organization for Economic Cooperation and Development.

Being inside the fast-changing and competitive U.S. market brings two advantages. First, new developments can be transmitted more rapidly to the European parent company, so that it can compete with U.S.-based and other European firms as new products and methods are introduced in Europe. Second, a corporate lead in high-income, labor-saving products in the U.S. prepares a European firm for competitive battles in Europe, as European markets take on "U.S." characteristics.

A good many European managers admit the need to learn-by-doing in the U.S. in order to face what U.S. companies (or more daring or lucky European competitors with U.S. operations) might employ on the European market in future.

Olivetti is one company that has not hidden its desire to learn from U.S. marketing and technology. Plessey is another European group that has publicly stated its desire to learn from U.S. practice. In its proposal to shareholders for the acquisition of the U.S. firm Alloys Unlimited, Plessey stated that the acquisition would allow it to "acquire immediately a number of products and know-how which are important to our successful development." Plessey's deputy chairman notes that it "would be uneconomic for us or any other European manufacturer to learn (on his own) the skills evident in the Alloys organization."

A similar rationale underlies part of Unilever's long-standing interest in U.S. operations. And managers of one European petroleum company commented that "in order to be really successful in Europe and elsewhere, we have to compete in the market where the greatest petroleum marketing advances are being made. We have to compete in the U.S. by direct investment operations because the quota system prevents us from simply exporting to the States."

In all, nearly 50% of the European company managers interviewed in this study emphasized the importance of being in the U.S. in order to "feed back" technical or marketing skills to the mother company.

In one of the most notable cases of a significant product breakthrough by a European firm in its U.S. subsidiary - Sandvik Steel's development of "throwaway" carbide cutting edges - perhaps the most significant factor was the fact that the Sandvik group's development director at headquarters had himself worked for two years in the U.S. and was receptive to new product improvements. He was able to convince group management of the usefulness of transferring this innovation from the U.S. to European operations. A development team from headquarters was sent to the U.S. to work with the U.S. R&D group and further develop the new product. These improvements have accounted for a great deal of Sandvik's impressive growth during the last decade and now account for no less than 40% of the group's worldwide sales.

The majority of large European companies with U.S. operations are in relatively high-technology industries. 21 of the 49 firms examined - or nearly half - are in the "secteurs de pointe" in which Jean-Jacques Servan-Schreiber so feared American domination of European industry. These sectors are chemicals, pharmaceuticals, machinery, and electrical machinery. The average percentage of sales revenue spent by the 49 firms on research and development was an impressive 3.7%, without doubt a figure far above that of European companies not investing in the U.S. Indeed, if one compares this figure with the data available on most international U.S. corporations, it is still high.

Not only do European companies investing in the U.S. seem to have more technological competence than other European companies, but, within the former group, those companies that spend heavily on research and devlopment have done much better in terms of sales growth in the U.S. than those that do not. There is a significant correlation (.67) between the percentage of total revenue which companies in our sample spend on R&D and their rate of sales growth in the U.S. market between 1965 and 1969. Almost all the European companies in our study that spent less than 1% of their total group sales revenue on R&D had stagnant or negative growth rates in the U.S. during those five years. Also, there appeared to be a relationship between total group revenue spent on R&D and U.S. profit growth over the 1965-69 period (the correlation coefficient was .7 for 10 companies for which we had sufficient information).

The primary reason for European companies' preference for wholly owned ventures in the U.S. (and incidentally for the high joint-venture divorce rate) seems to be related to the nature of the U.S. market. The desirability, perhaps the necessity, for a European company to do R&D in the U.S. has already been mentioned. Yet, insofar as "the management of technical innovation is much more than the maintenance of an R&D laboratory" but is rather "a corporate-wide task...too important to be left to any specialized functional department*... the subsidiary's response to the ever-changing U.S. market may require a closer coordination between marketing and R&D than is possible with a joint-venture relationship.

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*Based on 23 companies for which data were available. The reader should be warned that this and other correlations could be the result of other factors that, for one or another reason, could not be examined. They should be interpreted in the context of other qualitative evidence presented.

Although generalizations are perilous, the case of a company that had a joint venture with its one-time U.S. importing agent during the first few years in which it manufactured in the U.S. seems typical. Prior to developing its own marketing competence under its own ownership umbrella, this subsidiary was effectively cut off from new developments in its marketplace and was not able to get information about new applications for the particular product it produced. After buying out its partner's sales network, it was able to reintegrate the marketing and R&D functions in the U.S., and went from rather dismal failure to quite considerable success over the subsequent five years.

Acquisition seems to provide the quickest way to learn U.S. technology and marketing skills that are new to a European group. This was a key reason for Plessey's acquisition of the U.S. company Alloys Unlimited. The acquisition by a European oil company of a small U.S. refinery had a similar motivation - but this time for purposes of learning marketing skills rather than technological skills. The European firm's executives remarked that they felt, in order to be a viable worldwide petroleum company, they had to learn marketing in the market where most of their major competitors came from. The company did not feel that its marketing was strong enough to enter the U.S. first by setting up an exploration company and then gradually working its way into competition in refining and distribution with other U.S. petroleum companies.

A pharmaceutical company, which originally entered the U.S. shortly after World War II by forming its own subsidiary, noted that it had recently taken over 100% of a U.S. hospital supply company. The company indicated that as far as possible it preferred to avoid acquisitions "and the digestion problems that acquisitions usually cause," but that in this particular case it felt that the pharmaceutical business was changing so rapidly that it could not take the time to learn medical electronics and hospital servicing without making such an acquisition.

One experiment designed to address the problem of technological lag and insufficiency of funds is the National Research Development Corporation (NRDC) in the United Kingdom. This is an independent public corporation, financed by government loans, established in 1948 under the Development of Inventions Act whereby new high risk R&D ventures can be funded. The fields covered are the biosciences, industrial chemistry, scientific equipment, mechanical engineering, production engineering, electrical engineering, electronics, computers and automation. NRDC assists the advance the advance of technology by investing money primarily in joint R&D ventures with industrial firms and also with private investors, and receives a fair commercial return on its investment. The Government gets a portion of the business and a percentage of the profits, and also has a seat on the Board of Directors. The profits derived from these ventures are reinvested in other high risk technological ventures. Two of the noteworthy successful projects were the Hovercraft and cephalosporins, one of the most significant groups of antibiotics discovered since penicillin. The latter was one of the largest royalty earners ever to have emerged from academic research, and represents an excellent example of the type of basic invention that NRDC was expected to handle when it was established. Not only has the Crown's initial investment been repaid but the revolving funds have brought about the funding of many other R&D projects in high risk technology. These include major contributions to the establishment of the electronic computer industry; development of selective herbicides; development and production of the first high speed linear motor hovertrain and of the first large superconducting electric motor; extensive research and development of fuel cells later used as the basis for the power plant in the Apollo moon-landing program; etc., etc.*

Attempts have been made to evaluate contributions of NRDC-supported innovations at the national level but appropriate techniques of measurement are still controversial. The Corporation believes that, unlike other

*Evidence Offered to the Committee to Review the Functioning of Financial Institutions (The Wilson Committee), (London, England: NRDC, 1978).

sources of venture capital, its success will not be judged solely by reference to its balance sheet. It's aim is to continue to create new business opportunities in the U. K. from the research work and inventions available to it, with increased employment prospects and foreign currency earnings from exports or license income. The total NRDC investment in both private and institutional support is not large; the rationale is that:

> The cost of most of the civil development work in this country will continue to be met out of industry's own resources but there may be cases where individual firms are unable to undertake, entirely at their own expense, the development of potentially valuable projects. In the export field the need for the United Kingdom to develop and market technically advanced products against strong international competition puts a heavy development burden on much of the country's manufacturing industry. In such circumstances there may be merit in a collaboration between industry and NRDC.
>
> It is a natural consequence of the Corporation's statutory functions that it is prepared to undertake projects where the degree of risk is greater than that which a commercial undertaking would regard as justified.*

Having operated at a deficit for its first 27 years, the Corporation for the first time in 1975-76 was able to carry forward a net surplus. The total investment in external R&D support over that period (1949-76) was 48.2 million pounds sterling (about $87.4M at current exchange rates).** In 1977 alone it is estimated that the gross amount of new industrial production which the NRDC helped to generate was 100 million pounds sterling ($181.25M), with a ten year accumulated total of 600 million

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*National Research Development Corporation: An Introduction (NRDC, London, October 1970).

**27th Annual Report and Statement of Accounts 1975-76 (London, England: NRDC, 1976).

pounds ($1.1B). Also sales of the ICL 1900 Series computers, towards the development of which NRDC contributed approximately four million pounds ($7.25M), have now reached 1.1 billion pounds ($2B), while direct foreign currency earnings by NRDC from products licensed overseas have so far exceeded 50 million pounds ($90.6M).*

Some rather similar experiments by the small business investment companies (SBIC) in the U. S. have foundered. Because of its relatively small size, the typical SBIC has had difficulty in developing a competent staff to tackle the formidable appraisal problem and in carrying the necessary overhead to administer a complicated portfolio of new technical enterprise investments. The time required today to reach the stage of profitability is usually several year longer than originally anticipated.

A Research and Development Incentives (RDI) program of the National Science Foundation attempted to pursue a similar program, offering to share with industry the funding of early development of a new type of aluminum processing. The response from industry was overwhelmingly negative, since the large companies had large investments in existing equipment, processes and products. However, a second such program has received backing, and is now under way. This concerns a gas-fired turbine engine whose development is being funded equally by DoE, the Gas Institute, and General Electric Co. All rights of manufacture and licensing belong to G. E. Acceptance of such a philosophy seems to be closely linked to the perception of public good.

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*Figures taken from evidence provided the Wilson Committee, op.cit., and converted at an exchange rate of 1.81 dollars to the pound, quoted in The Economist, May 27, 1978.

9. Policy Options

Since the national perception is that the United States must remain in the forefront of technological development for its well-being, we must examine the various policy options available to us as well as the means by which we may most expeditiously obtain the desired goal.

As we have indicated in the discussion thus far, the progression from ideas to inventions to innovations and finally to imitation or diffusion of the idea or the invention is highly complex: the total process cannot be facilitated by only one set of actions. We must separately examine how we can best enhance or encourage the generation of ideas and invention, and then examine the method of converting or utilizing these inventions through innovations and diffusion. In this section we will briefly mention a few of the options available to us, and their implications. In subsequent sections we will summarize our findings, and suggest a program designed to identify the most appropriate Governmental actions.

Stimulation of the innovation process could be accomplished by establishing a national focal point (or possibly more than one), which may also serve as a source for funding research which is not directly mission-oriented. The actual research can be performed both in national laboratories, such as the National Bureau of Standards, the Oak Ridge National Laboratory, or the Naval Research Laboratory, or by individual private organizations.

In the second area, that is the encouragement of the movement of inventions and innovations into the mainstream of mature production industries other approaches will be necessary. First, a broad review and possible revision of the current anti-trust laws appear to be appropriate.

It is important to recognize the negative psychological effects on the attitudes of management resulting from the arbitrary enforcement of anti-trust statutes which militate against the pooling of research information between companies. Incentives could be provided to encourage the search for "quid pro quo" arrangements which would benefit the industry as a whole, and also avoid wasteful duplication of effort. This is especially significant in view of the growing scarcity of qualified research personnel. Of equal importance, we visualize the need for the modification of the current tax structure through investment credits, which will encourage the rapid introduction and integration of new product ideas into product lines.

Mansfield* has shown that the spread of innovations (or if you will the diffusion of ideas) is highly dependent upon the investment to be made by the organization which is applying that idea and the risk involved. Both factors can be attacked by the government in providing either additional funding to support the introduction as well as reducing the risk involved in failure.

Not only must we be concerned with the provision of funds and possibly relief in the tax area but we must also recognize that there are federally imposed requirements which tend to burden various high technology companies. An example of this type of burden is found in the requirement for the utilization of equipments and devices to purify or improve the environment -- an example might be a chimney smoke scrubber. In the past these

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* Mansfield, E., The Economics of Technological Change (W. W. Norton & Co., 1968, pp. 99-133.

additions, which are required for the social good rather than the direct economic good of the nation, have been handled as if they were capital investments. A modification of this procedure wherein these costs could be written off much more quickly would be directly of benefit to the industry and the economy.

In certain high technology areas it might be appropriate that a technology impact statement be prepared, analogous to an environmental impact statement, for consideration by the Government or other central bodies in determining appropriate supportive and/or regulatory actions, such as whether or not the technology should be exported. This is not to burden the proposer nor to delay nor extend the time required to move a new idea into full production, but it would permit a quick evaluation of the broader impacts by requiring the answers to specific judicious questions. Some formalization and extension of the functions of the old National Munitions Board could be implemented and formalized into a separate element or as a more visible segment of either the State Department or the Commerce Department.

In summary, the options available to the United States in enhancing and fostering the technological lead of our country are numerous. The selection of the appropriate actions, however, requires a much more thorough understanding of the processes involved in developing the technology and the movement of that technology into the market place as well as the consequences of transferring that technology at an early point to other competitive nations.

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10. Conclusions and Recommendations

In this section, we will present both the conclusions we have reached based upon consideration of the issues discussed thus far, and our recommendations for responsive Government action. Some of the recommendations are more specific than the foregoing materials would indicate, due to time and space constraints; however, they are a logical consequence of the basic contentions around which this presentation has been built. In particular, it is apparent that the interactions between technology and the national economy constitute an exceedingly complex system which we do not totally comprehend. In attempting to understand it we are forced to work with very gross statistics. For example, we have compared industries on the basis of the relationship between level of sales and expenditures for R&D, but the definition of "R&D" is imprecise. It may include everything from minor design changes or adjustment of formulations, to work at the extreme frontier of science. Within an industry, "communications equipment" spans a spectrum from telegraph keys to fiber optics. We do not have an explicit and acceptable definition of technology, and most certainly we have no agreed-upon unit by which to measure it. If the technologists themselves had to work with data so imprecise and concepts so fuzzy, we would still be chipping flint. Before any cohesive policy can be developed to address the related problems, we need more precise definitions of our terms, and a better understanding of their correlations.

We do know that the entities which we lump together under the rubric "technology" form a complex interactive system; and we know enough about such systems to be aware that it is impossible to change only one factor.

To achieve a desired goal in one area it may be necessary to accept an undesired consequence in another. An example may help to illustrate this point.

In 1956, as the result of an anti-trust suit which began in 1949, Bell Laboratories began to license transistor patents widely, both at home and abroad, and to provide "know-how" to the licensees. One consequence of this was that transistor technology spread rapidly throughout the American electronics industry - a desirable outcome, and healthy for the national economy. However, a less desirable result was that other industrial nations since then have been only a short step behind our technological lead in this area. As we pointed out earlier, this is an economically viable role to play, and the United States is no longer dominant in this market.

Large electronics companies are now being harassed under anti-trust laws which seem to have been designed for the industrial conditions prevailing in the time of Teddy Roosevelt. The position should be re-assessed in view of changes over the last 80 years. The current applications of these statutes appears designed to combat size, not to preserve competition. (We refer specifically to the cases of IBM and Bell Telephone.) While this harassment continues, simultaneously:

1) other countries are trying to develop a comparable "national champion" in selected technologies, i.e. computers, telecommunications, etc.; and

2) technological developments such as microprocessors are weakening the country's competitive advantages.

The point which we wish to stress is that the nation should make every effort to find ways of describing this dynamic system we call technology as a first step towards seeking means of optimizing its contributions to the national welfare. For this reason we are particularly pleased that these Senate subcommittees are jointly undertaking the present investigation, and hope that the knowledge gained will be used to guide the many government actions which impinge on the system. Tax policy -- especially the treatment of depreciation in the light of inflation, and the taxation rate for capital gains -- anti-trust actions, tariff and trade policies, environmental protection and many other factors impinge on technology. As the service sector of our economy employs an ever increasing percentage of our labor force - 76% at present, and predicted to reach 80% by 1980* - it becomes crucial that the nation receives adequate recompense for the knowledge/technology which constitutes the output of this sector. We cannot tolerate the uncontrolled and underpriced outflow of this precious resource.

It appears clear that those agencies which undertake or support R&D should rethink their role in developing technology. The government has played an important part in stimulating development of leading edge technology at least since Eli Whitney and the first assembly line (for muskets). The need for things like the railroad, the telegraph, large computers may have been obvious at the time, but we cannot afford to wait nowadays until the need becomes obvious and the critical inventions are in hand.

A deliberate search seems to be indicated for areas of technology likely to become important, to establish long range missions where future requirements can be identified. This is not to be confused with basic research; it is concerned with mission-oriented research with a long lead-time, where the pay-off for private companies is too uncertain to justify

*Cetron, Marvin J., and Don H. Overly, "Disagreeing With The Future", in Technology Review, March/April 1973.

the funding requirements. But long lead-times and high risk do not imply that the social returns are low. It may be an irreparable mistake, for instance, to restrict the National Bureau of Standards - previously one of the world's best long-range technology research laboratories - to short-range goals.

The Mansfield amendments, which limited DoD-funded research to mission orientation,* was successful in stopping "hobby shop" research, but it may also have closed off a major source of leading-edge technology. The decline in the activities of the Naval Research Laboratories and of organizations such as NASA, for example in the area of domestic satellites, may seriously affect our leadership position in the next twenty years.**

As our earlier discourse has indicated, the key resource of the technological leader is lead-time. It is essential that we capitalize upon this resource, that we be quick to innovate, and quick to commercialize and market. This requires, <u>inter alia</u>, that we bring together entrepreneur finance and management/marketing skills. This problem should be addressed, as well as the phenomenon that small companies are more likely to innovate, but less equipped for large scale production and marketing.

In short, the structure which seems to be appearing based on our review of these issues and our experience as a concerned institution, is as follows:

1. While other roles are economically viable, the generally accepted perception of the U.S. is as a technological leader. This implies that at any given time we possess "intellectual property" having certain characteristics which are (temporarily at least) unique to the U.S.

2. Dispersion is an intrinsic and essential component in the life-cycle of technology. The dissemination of the technology, and the transfer of such intellectual property, cannot and should not be prevented; it can and should be controlled and delayed.

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*Except where explicitly approved by the Secretary of Defense.

**The Japanese are advancing strongly in satellite communications. (See <u>Satellite</u>, March 1978).

3. The technological leader is burdened with the greatest expenses and risk. Consequently he should receive some form of compensation -- financial, and/or a reciprocal transfer of information -- for technolgical outflow.

4. A continuing flow of new technologies is necessary as a replacement for those whose application and benefits pass into the hands of other nations.

5. Financial and regulatory concessions/incentives are needed to encourage such a continuing flow.

6. The nature of technology and its interactions with the national and international socio-political-economic system are complex and difficult to describe. As a result, a change in one factor has ramifications which in our present state of understanding are not immediately comprehensible.

In view of these findings, we believe that our national policy should be built around the following goals:

- to understand the nature of technology and the various factors which govern its creation, dissemination, commercialization, and contributions to the national welfare;

- to encourage a continuing stream of creative technological innovation within the U.S.;

- to develop and institute a coordinated system of controls and incentives which will assist in the optimization of national benefits resulting from technological innovation and application.

It is with these objectives in mind that we have drawn up a set of initial recommendations for consideration by this Committee. Both specific and general issues are addressed, and the list is to be regarded only as a basis for further review and examination. We present this set in the form of two subgroups, each of which requires that you authorize and/or execute related investigations. The first set calls for direct action on the part of the Congress of the United States. Recommendations in the second group require Congressional approval and active encouragement for their expeditious implementation.

In the first group, which we believe to be of direct concern to this Committee, the following specific items are included:

1. A committee of the United States Congress should examine the desirability and feasibility of specific legislation requiring evaluation and approval of the transfer to foreign industrial production facilities of high technology weapons. On a more general level, monitoring and/or controls should also be considered in connection with the transfer off-shore of any high technology. An appropriate component of the monitoring process would be the requirement for filing a "technology impact statement" in advance of potential technology transfer. Such a statement would explore the costs and benefits to the U.S. of the proposed transfer of technology to a foreign location, not only in monetary terms but also in terms of future technological and socio-political implications. Obviously, the establishment of such a requirement would in itself mandate the need for a thorough investigation of what factors should be included in the technology impact statement.

2. A committee of the U.S. Congress should reevaluate the relevance, in the context of our current technological status, of the Mansfield Amendment which restricts the Department of Defense from the performance of non-mission-oriented research.* Such a restriction may no longer be appropriate.

3. A committee of the U.S. Congress should examine the charter and experience of the National Research Development Corporation in the United Kingdom. This organization funds the development of new innovations and provides some mechanisms for the transfer of those innovations into industry. A similar body could be established in the United States and could be very appropriate in view of our current needs. Such a board might include for example: one member of the Academy of Sciences or Engineering from the appropriate discipline; one member of the President's Economic Advisory Council; one member of the relevant technical institute or society (e.g. Institute of Electrical and Electronics Engineers or American Chemical Society); and one from the appropriate industry Association (e.g. the Electronics Industry Association or Pharmaceutical Manufacturers Association).

4. A committee of the U.S. Congress should examine the current charters both for the Commerce Department and for the Small Business Administration to determine whether changes might not be appropriate based upon the current situation. Specifically, we would suggest that the Small Business Administration, SBA, could play a significant role in supporting high technology ventures in small organizations. At the same time, the Commerce Department could be redirected so that it would not only provide advice to industry concerning foreign and domestic market

* Unless a specific exception is approved by the Secretary of Defense.

potentials but could also assume the leadership role in a somewhat similar fashion to the Ministry of International Technology and Industry (MITI) which has been very successful in the Japanese context.

5. A committee of the U.S. Congress should reexamine the current anti-trust policy and statutes. It should reassess the ultimate benefit to the United States' economy of the application of these laws to a corporation based on its size rather than its activities in constraining and restricting trade. The competitive status of the nation as a whole could benefit from appropriately monitored cooperative ventures between industry leaders and the encouragement of internationally recognized centers of excellence.

6. A committee of the U.S. Congress should explore methods of allowing small and innovative organizations in particular, but also large corporations when appropriate, a rapid write-off for capital investments which are required for environmental protection or occupational safety. These investments do not contribute to the actual productive or R&D capacity of the organization and therefore an equitable write-off procedure should be developed as a replacement for current regulations.

7. A committee of the U.S. Congress should examine the problem of establishing equitable methods of depreciating high replacement equipment costs due to inflation and, at the same time, consider more favorable approaches to depreciating capital expenditures required to perform R&D.

8. A committee of the U.S. Congress should explore the feasibility of extending the concept and coverage provided by our patent laws to such new arts as the development of computer software or semi-conductor device masks.

The remaining recommendations are less well focussed but also merit your serious and deep consideration, although specific actions may be less clearly identifiable at this point in time. These include the following suggestions:

1. Methods of encouraging and facilitating Government-industry-academic cooperation should be examined. One such mechanism could be a series of governmental/industrial committees, similar to the MITI organization in Japan, to offset the adversarial relationship which frequently exists between government and industry. It would be necessary to examine possible transgression of federal procurement or related regulations.

2. Efforts should be made to strengthen government laboratories and increase the expertise needed to facilitate the commercialization of the results of mission oriented R&D. NASA has instituted various programs to accomplish this, but there is a need for more to be done -- the question is how and when. This may very well be appropriate for a committee of the Congress to begin to examine.

3. As a corollary to the two above recommendations, we suggest that such organizations as the National Bureau of Standards and similar centers of excellence should be funded on a long-term basis and be permitted to perform non-mission oriented research to provide the scientific basis for future innovations and diffusion of that technology throughout American industry.

4. A means should be found to permit the exchange of personnel between Government laboratories, industry and the universities, so that interpersonal expertise and information can flow throughout the "technology system". The question of how best to accomplish this should be examined in depth.

5. We suggest that the United States Government should in some fashion support graduate engineering and science students in their initial attempts to adapt to and be employed by industry. How this could be done is unclear; however, a program could be established to fund a portion of the salaries of graduate students who might be willing to work during the summer, both in small as well as large corporations throughout the United States. The advantages both to the industry and to the academic community would be significant.

6. An examination should be undertaken of means whereby merged or combined cooperative research can be performed in the United States in such vital areas as very large scale integration (VLSI), taking into account the current anti-trust laws. We must recognize that the Japanese have already been active in this particular area for some two years.

7. An urgent need exists for the proper definition and description of the dynamic system which we call technology. The effort must be undertaken by not one organization but by several groups where the results can be merged and over a period of time (possibly five to ten years) a better understanding of the complete interaction between the developing technology, the industrial application of the technology, and the economics involved both in funding the industry and in the return on their investment can be obtained. Whether this is appropriate for the Congress or not is unclear; however, the initial stimulus for such an undertaking should stem from the Congress.

8. There is a need to identify future technologies which are likely to become important to the national interest. The identification of these technologies and the nurturing of them over a long

period of time should be the responsibility of not one specific organization but several. Whether appropriate organizations exist within the current structure or not is unknown but some thought should be given to this particular point so that the greatest advantage can be obtained to the United States.

In summary, we are in favor of a policy designed to increase the supply of technology and thus the amount that may safely be exported at a reasonable price. This would seem to be both practical and productive, and thus the government can significantly foster and encourage the process of technological innovation, and sharpen our competitive edge in the world economy. We believe that the Congress can act as a spearhead not only in investigating and providing the legal foundations for some of the actions required, but in stimulating universities, industrial organizations and the Federal Government to undertake and to carry to fruition those activities necessary for a vital and dynamic America in the third century of our existence.

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STATEMENT OF
AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC.
SUBMITTED FOR RECORD
OF JOINT HEARINGS OF
SUBCOMMITTEE ON INTERNATIONAL FINANCE
OF THE COMMITTEE ON BANKING, HOUSING AND URBAN AFFAIRS
AND THE
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY AND SPACE
OF THE
COMMITTEE ON COMMERCE, SCIENCE AND TRANSPORTATION

May 1978

The Aerospace Industries Association of America, Inc., representing 48 of the nation's major manufacturers of aircraft, spacecraft, missiles and related components and services, appreciates this opportunity to comment for the record on the competitiveness of U. S. high technology exports in world markets. As leading producers of high technology products, aerospace manufacturers are extremely concerned about erosion of America's long heralded technological superiority. It is apparent that exports play a vital role in strengthening the U. S. economy and the facts show that the U. S. is losing market position in certain high technology products at a time when the nation can ill afford such a trend.

In 1977, the U. S. aerospace industry generated $32 billion in sales, of which $7.6 billion -- 23 percent of the total -- was exported. Some 900,000 people are employed by the industry and we estimate that approximately 200,000 of that number owe their jobs to the export market.

Historically, U. S. manufacturers have been the dominant force in the world air transport market, having risen from about 72 percent in the late 1950's to approximately 95 percent of the market value during the early 1970's. (Graph 1) However, this share has now fallen to about 80 percent as European

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companies achieve airline acceptance with such transports as the A-300, Mercure, VFW-614, Trident and Concorde, as well as with aircraft engines built by Rolls Royce and SNECMA.

Compare, for instance, U. S. aerospace revenues with those of France, the United Kingdom, and the EEC on an index basis with 1970 as the base year. (Graph 2) By 1975, France's revenues had grown by 35 percent, the U. S. by 31 percent and the EEC by 27 percent. For the same period, the U. S. dropped to 72 percent of its 1970 level.

In addition to transport aircraft, the U. S. aerospace industry exports an array of other products, general aviation aircraft, helicopters, engines, parts, spares and accessories and, certain items which fall within the category of arms. The latter, of course, are also high technology exports. In 1970 (Graph 3), the total world military export market amounted to $6 billion, of which the U. S. share was 53 percent and the Soviet Union's share 26 percent. The 1975 proportions of the total were similar, with the U. S. shipping $4.9 billion and the Soviets $2.6 billion, assuming the latter figure is not underestimated. Therefore, it is evident, again using 1970 as the base year, that the U. S. has not accelerated its arms exports any more than the other arms exporters. France, in fact, has increased such shipments threefold from 1971 to 1975, and West Germany and the Soviet Union have approximately doubled such exports in the past two or three years.

In short, although high technology products still make a positive contribution to the U. S. balance of trade in all five categories identified by the National Science Foundation, a leveling trend is now at work. (Graph 4)

Why is this happening? We believe there are five reasons, to wit:

- o Our R&D performance is in need of revitalization;
- o Our capital investment needs upgrading;
- o Our traditionally high level of productivity is being challenged by other industrialized nations;
- o The value of the U. S. dollar is deteriorating relative to foreign currencies;
- o There is uncertainty as to future U. S. government policies governing all such matters.

Why are many other industrialized nations becoming more competitive in high technology? Investment trends provide a partial clue.

The U. S. lags behind its major competitors (Graph 5) in both real private fixed capital formation growth and as a percent of GNP. Since 1972, the U. S. recorded a four-percent drop in capital formation -- a decline of 14 percent as a percent of GNP. We have demonstrated a reluctance to invest in the factors of production that are so necessary for the maintenance of modern efficient plant and equipment. Simply stated, we are permitting Japan, Canada, France, and even the U.K. and Italy to outdistance us in capital formation.

Additional evidence of the U. S. capital shortfall is the fact that Western Europe, Canada, Japan and more recently the OPEC countries are seeking to fill this capital vacuum. The Treasury and Commerce studies commissioned by the Foreign Investment Study Act of 1974 reported that foreign cumulative direct investment in the U. S. jumped from just under $9 billion in 1965 to nearly $27 billion in 1975 -- a three-fold increase in only ten years. The best informed sources estimate that these past two years provided bumper markets for the foreign investors in U. S. industry. For obvious reasons the OPEC countries have been especially active U. S. investors in recent years.

A second area of U. S. deficiency is the level of research and development. Such investment is one of the most reliable measures of a country's future political objectives and economic goals. (Graph 6) Most of the R&D performed throughout the world can be attributed to seven nations: the Soviet Union and the six depicted in the chart. Differences in Soviet definitions and accounting make comparisons with that nation most difficult, hence its absence from the graph.

The U. S. differs significantly from the other major R&D performing nations in that a larger share of our government-funded R&D is allocated to defense and space. Currently, the U. S. allocates roughly 60 percent of the government's R&D funds to these two categories of expenditure. Japan, on the other hand, is spending only 7 percent in these areas.

For the advancement of knowledge -- basic research -- the U. S. has been allocating less than 5 percent, while the U. K. -- second from the bottom -- finds 20 percent for this purpose. West Germany and Japan are allocating 50 to 55 percent of their total available R&D money to this field, a cause that will undoubtedly pay handsome dividends in the future. Perhaps more importantly than the allocation, is the fact that since the early 1960's many of these countries, including the Soviet Union, have been increasing expenditures for R&D as a percent of GNP. In 1964, U. S. R&D expenditures stood at about 3 percent of GNP; today it is no more than 2.2 percent.

In addition to the steady increase in R&D performance, our industrialized competitors are showing the same upward trend in the employment of scientists and engineers. (Graph 7) The U. S. experienced a 9 percent decline in the number of professionals engaged in R&D per 10,000 population from 1969 to 1971. The rate has remained constant for nearly a decade. In the meantime, the employment of scientists and engineers in R&D rose at a faster rate in the other countries than did their total population. Not only has the proportion of R&D scientists and engineers per 10,000 population in the U. S. declined, but the actual number employed has fallen by some 26,000 between 1969 and 1975, most of which came out of aerospace.

These trends -- capital investment, R&D funding and trained professionals -- are three major inputs to productivity. Many other factors affect productivity growth: technological change, management organization and systems, imported technology, and changes in social, economic and political institutions. While it is impossible to measure the impact of each of these factors, it is generally agreed that advances in technology increase productivity more than any other single factor.

In terms of growth in the output per man-hour (Graph 8), Japan -- with 105 percent growth since 1967 -- has outpaced the other countries shown. During the same period, U. S. productivity has grown only 22 percent. Even the U. K. witnessed 25 percent growth, while West Germany jumped 62 percent. Prior to 1967, the U. S. was showing greater increases in output per man-hour than the other countries.

Trends in workers' compensation (Graph 9) in recent years tend to favor the U. S. In 1960, hourly compensation in U. S. manufacturing was more than double that of any other country except Canada. Now, fifteen years later, the difference has narrowed or has been eliminated entirely due to large compensation increases abroad and the weakening of the U. S. dollar. In terms of unit labor cost, large wage increases along with falling or marginal increases in productivity in 1975 led to increases in unit labor cost of 11 to 15 percent in the U. S. and Canada, over 20 percent in Japan and France, and over 30 percent in the U. K. West Germany, with a 7 percent rise, was the only country lower than the U. S. Thus, this indicator is one area in which we appear to be at least competitive, and as the wage rate gap continues to narrow the U. S. could be producing at unit labor cost levels below some of the countries shown in the comparison.

The current devaluation of the U. S. dollar in the international money markets can be compared to a slow-burning fuse on a bomb that is ready to explode. (Graph 10) Between 1970 and 1976, the U. S. dollar lost 10 percent of its international buying power; between 1977 and 1978, the decline was 5 percent. It has been said that the recent rapid decline of the dollar will make U. S.-manufactured goods more attractive in the world marketplace. That can only be true for the short run, and the long-run implications are far more serious. If the dollar continues to devalue, OPEC could very well begin to quote oil prices in some other currency and the increasing cost of imported goods would perhaps result in import controls as a means of reducing the trade deficit. If import controls are imposed by the U. S., our trading partners could in turn impose controls over the goods which we export to them.

In addition to policies governing capital formation, government-funded research and development and devaluation of the dollar, the low level of government export promotion efforts and in some cases, government actions which would seem designed to actually discourage exports, are a final problem.

area. The Department of Commerce, for instance, has been reducing its activities in the promotion of U. S. exports, particularly in the area of aerospace exports, using the rationale that there is no "market entry" problem with aerospace exports. It seems somewhat shortsighted, however, to reduce government encouragement of exports which enjoy a positive balance of trade -- it would be more logical to support products demonstrating such a trend.

Again on the basis of comparison (Graph 11), the United States falls well below the average $35 million invested by our five closest competitors for export promotion. While the governments of Canada, France, and Japan each spent less than the U. S., these numbers conceal additional export promotion devices in those countries. Calculated as dollars spent per million dollars of manufactured goods exported, the U. S. spent only $338 per million compared with an average $900/million for each of the five other countries. Except for West Germany, which spent only $136/million, the other countries spent over twice as much, with the U. K. reaching a high of $2500/million.

Government policies toward such important export promotion devices as the Domestic International Sales Corporation, Section 911, and the Export-Import Bank have been equally inexplicable. Apparently it is the intention of the administration in the former case, and some members of Congress in the latter two cases, to weaken these useful institutions. In addition, imposition of such socially motivated export controls as the Arab boycott further undermines our trading position abroad. Although such policies affect all exports, the impact on high technology exports has been particularly noticeable.

Because it was our understanding that the Subcommittees wanted to concentrate on what the United States might be doing "wrong" with respect to high technology exports, we have not included complicating factors which result from what our competitors are doing "right" -- from their standpoint. Besides the aforementioned high levels of capital formation and investment in R&D, such countries deploy a number of political and economic non-tariff barriers and financing schemes which decrease competitiveness of U. S. high technology products. While it would not be within the purview of the U. S. Congress to cause the elimination of such factors, we feel that attention to the domestic U. S. factors already mentioned would help manufacturers of high technology products to compensate for such barriers until such time as these barriers might be eliminated by negotiation.

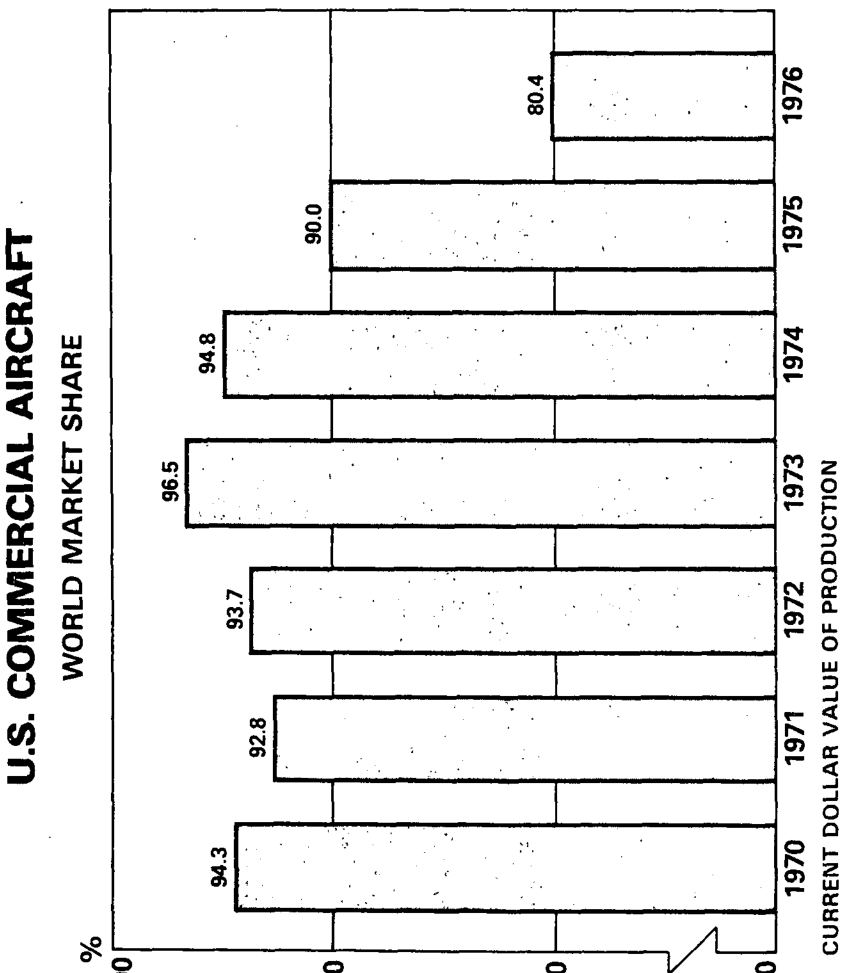
In summary, we feel that continued and increasing, rather than leveling, high technology market leadership of the U. S. aerospace industry is dependent upon the following:

- o A healthy and vigorous U. S. domestic economy capable of generating sufficient capital formation and market demand for U. S. products -- both domestically and internationally;
- o Long-term financial stability of the U. S. aerospace industry;
- o A joint effort between industry and government to maintain a superior technological base;
- o Long-term competitive financing for our customers, coupled with industry's ability to maintain a strong marketing and post-sales support program; and
- o A free and open world trade environment with equality of market opportunity.

Securing such an ambitious combination of policies and attitudes will be no easy task. Recognition that there may be a problem -- and we believe these hearings to be an encouraging sign that such recognition may be forthcoming

-- is an important first step. High technology has long been our greatest asset. In an atmosphere where sale and use of technology breeds more and better technology, export of high technology products is vital to maintaining the standard of living and way of life of most Americans.

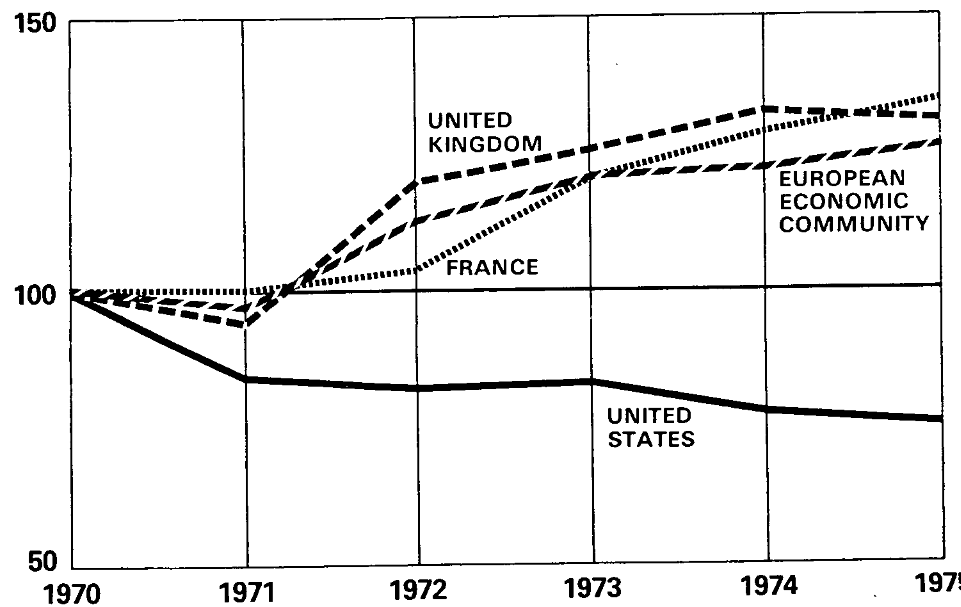
1


U.S. COMMERCIAL AIRCRAFT
WORLD MARKET SHARE
%
100
90
80
0
94.3
92.8
93.7
96.5
94.8
90.0
80.4
1970
1971
1972
1973
1974
1975
1976
CURRENT DOLLAR VALUE OF PRODUCTION

2

CHANGES IN AEROSPACE REVENUES

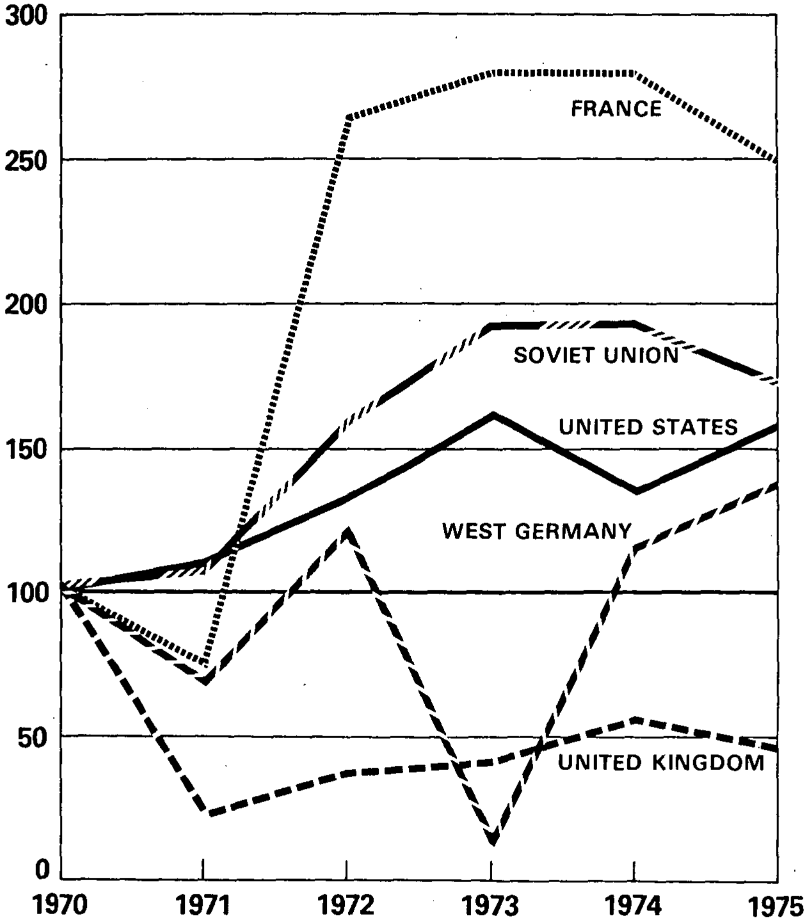
1970 = 100



3

ARMS EXPORTS

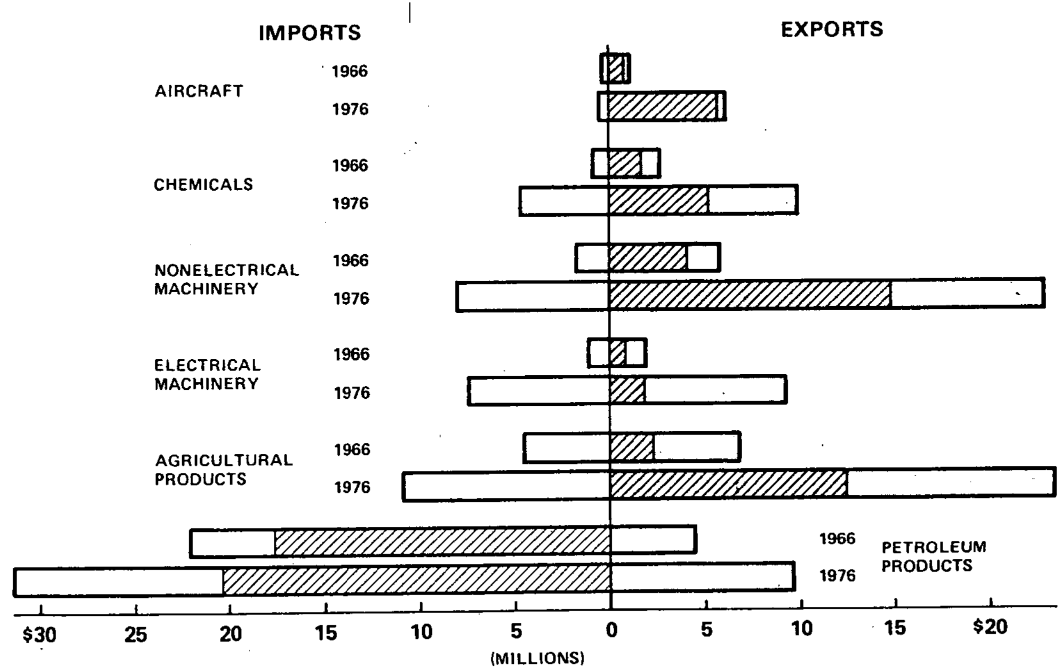
1970 = 100



4

U.S. TRADE BALANCE

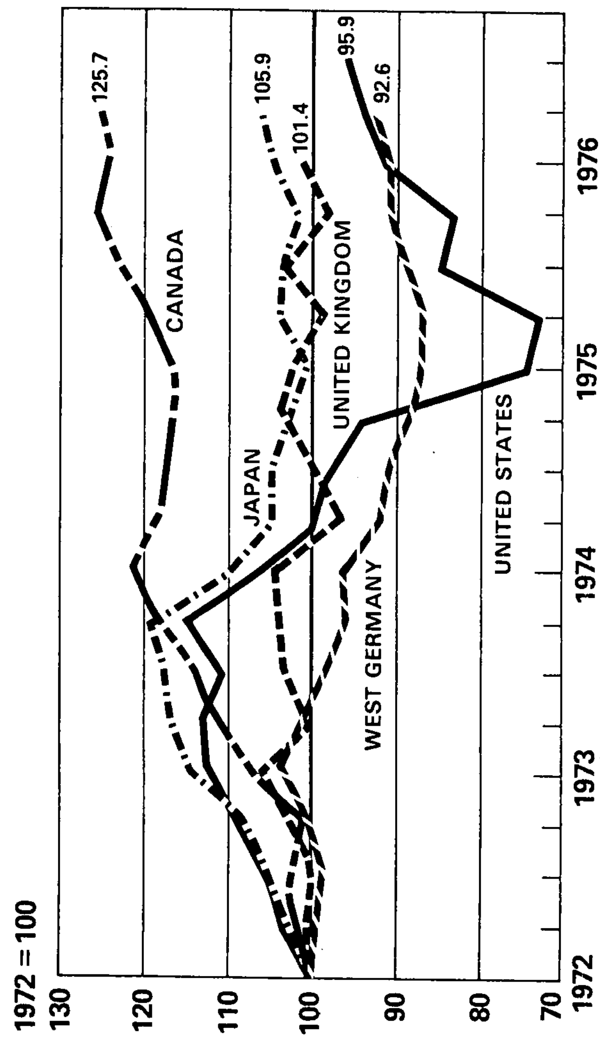
SELECTED PRODUCT GROUPS 1966 & 1976



5

INTERNATIONAL INVESTMENT TRENDS

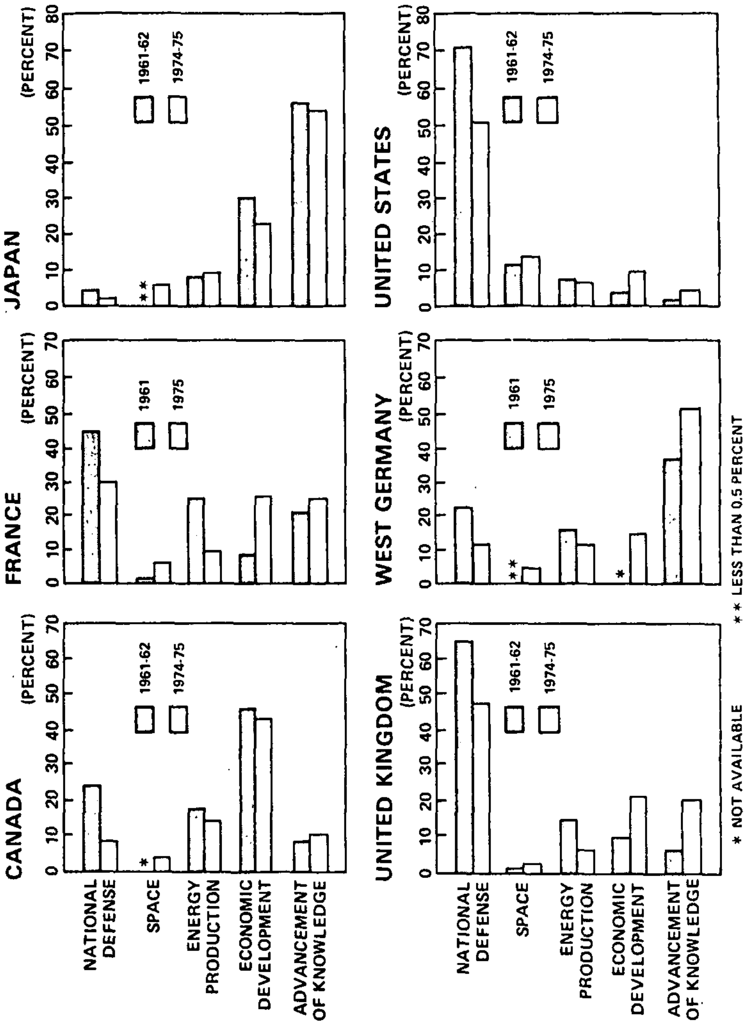
PRIVATE CAPITAL FORMATION



6

GOVERNMENT R&D EXPENDITURES

ESTIMATED DISTRIBUTION AMONG SELECTED AREAS



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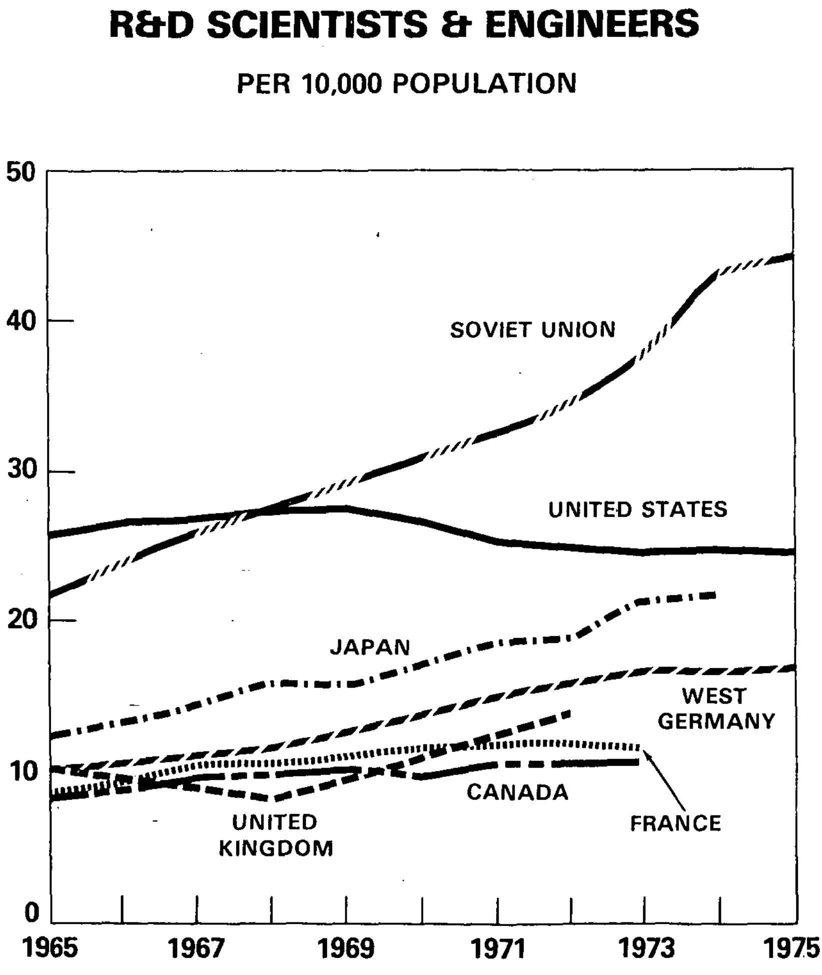
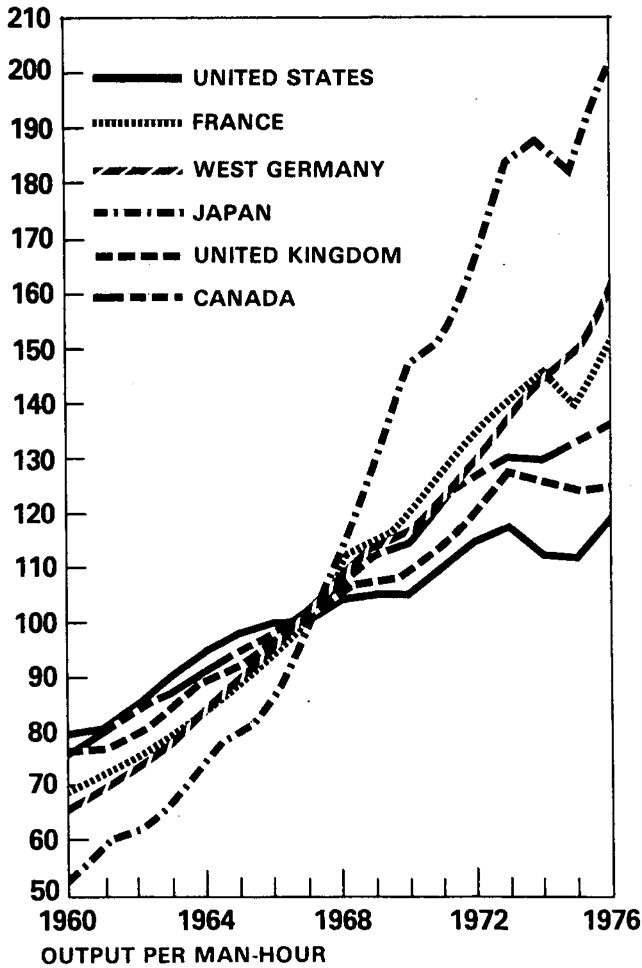

R&D SCIENTISTS & ENGINEERS
PER 10,000 POPULATION
50
40
30
20
10
0
SOVIET UNION
UNITED STATES
JAPAN
WEST GERMANY
CANADA
FRANCE
UNITED KINGDOM
1965
1967
1969
1971
1973
1975

8

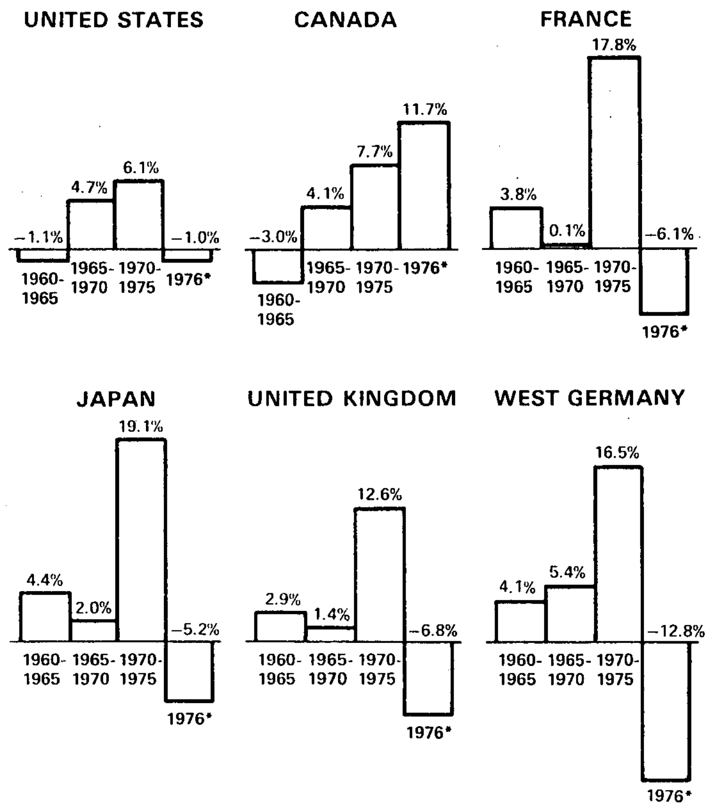
RELATIVE PRODUCTIVITY IN MANUFACTURING



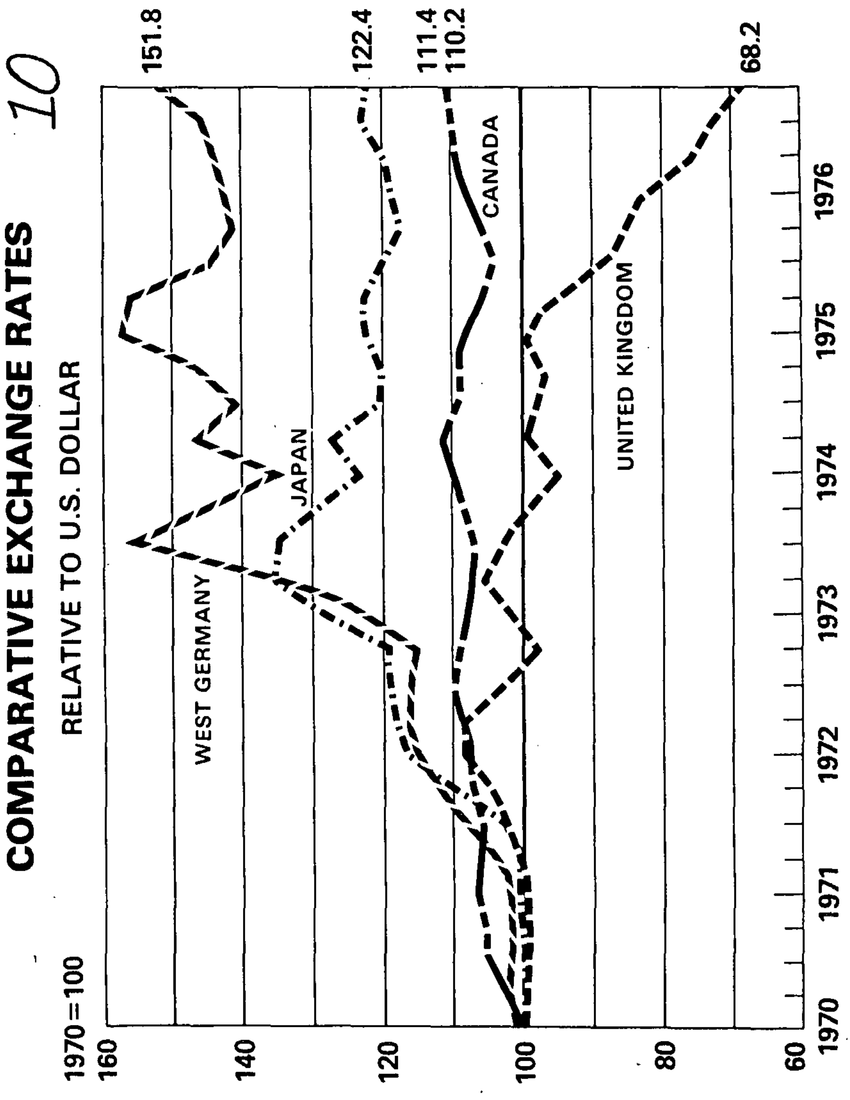
9

UNIT LABOR COST TRENDS
IN MANUFACTURING

AVERAGE ANNUAL CHANGE RATE, U.S. DOLLAR BASIS



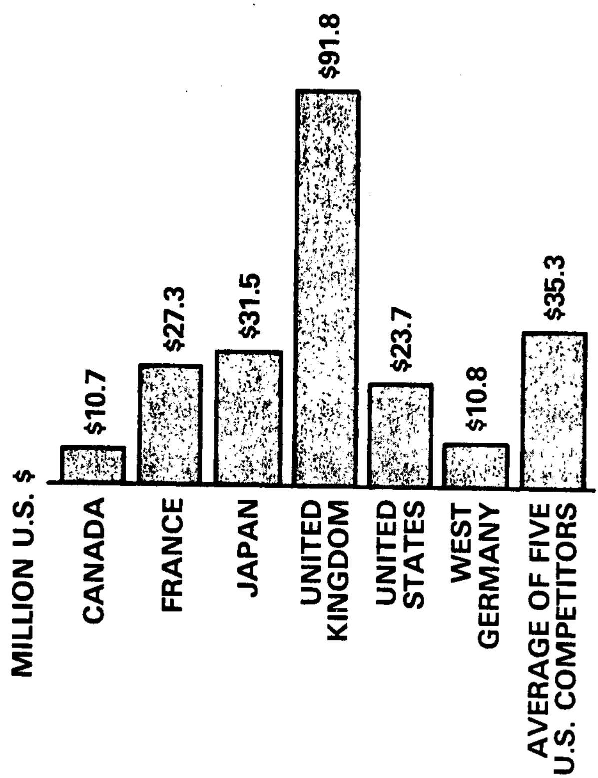
*ESTIMATES FOR 1976 COMPARE 1975 TO 1976, FIRST THREE QUARTERS FOR THE UNITED STATES AND FIRST HALFS FOR OTHER COUNTRIES.


10
COMPARATIVE EXCHANGE RATES
RELATIVE TO U.S. DOLLAR
1970=100
160
140
120
100
80
60
1970
1971
1972
1973
1974
1975
1976
151.8
122.4
111.4
110.2
68.2
WEST GERMANY
JAPAN
CANADA
UNITED KINGDOM

11

EXPORT PROMOTION EXPENDITURES, 1975

MANUFACTURED GOODS



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May 15, 1978

Honorable Adlai E. Stevenson
Chairman
Subcommittee on International Finance
Committee on Banking, Housing and
Urban Affairs
United States Senate
Washington, D. C. 20510

Dear Mr. Chairman:

I have followed with considerable interest the series of public hearings conducted by you and your Subcommittee in recent weeks which have focused upon the competitiveness of U.S. exports. A special concern which we share and which will be examined on May 16 by the Subcommittee is that of the competitiveness of high technology U.S. exports in world markets and the potential adverse impact on exports from declining research and development expenditures by U.S. Government and industry.

Through this letter, I should like to share several thoughts with you and the Subcommittee and respectfully request that its contents be made a part of the hearing record at the appropriate place.

We at Texas Instruments believe that any examination of the competitiveness of high technology exports should include a consideration of the adverse impact on exports that will result from regulations recently promulgated by the Internal Revenue Service. I recognize that your Subcommittee has no legislative jurisdiction with regard to the IRS; however, these regulations are so intertwined with the subject matter of your hearings that I would urge that the Subcommittee give them serious examination.

The regulations to which I refer (Treas. Reg. §1.861-8) provide new and complex rules for determining the amount of a U.S. taxpayer's total research and development expenditures which must be apportioned against the taxpayer's foreign source income. As a result of the application of these new rules, many U.S. taxpayers engaged in exporting high technology

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products will find themselves unable either to credit or deduct a portion of the income taxes paid to foreign governments. The resulting increase in taxes will be significant and will require U.S. companies not only to reassess the desirability of developing export sales rather than domestic sales but also the placement of research and development activities overseas to the detriment of the U.S.

Before the January, 1977 amendment of §1.861-8 of the Income Tax Regulations, U.S. research and development expenditures were apportioned against the U.S. taxpayer's foreign source income on the basis of the gross income of the U.S. company only. Now they are apportioned, through a complex formula, on a theoretical "worldwide activities" basis, the usual result of which will be an increase in the amount apportioned against foreign source income. Let me explain how this can result in companies with large research and development expenditures in the U.S. bearing an excessive tax burden. A review of foreign tax credit rules may be helpful.

(1) In order to prevent double taxation of income, foreign income taxes paid by a U.S. company (or "deemed" paid by its subsidiaries) are allowed as a dollar-for-dollar offset (credit) against U.S. income taxes up to the amount of the <u>foreign tax credit limitation</u> or ceiling.

(2) <u>Foreign tax credit limitation</u> is calculated as follows:

[Foreign source income] x [U.S. income tax rate]

(3) The new §1.861-8 regulations reduce the foreign source income factor in (2) above by allocating more research and development expenditures incurred by U.S. companies to it. Therefore, the foreign tax credit limitation or ceiling is reduced.

(4) With a lower ceiling or limitation, some foreign taxes may not be creditable against U.S. income tax, with the result that the overall tax burden is in excess of the U.S. tax rate.

As you can see the new rule provides an incentive to place research and development activities abroad where they are tax deductible and do not impact the foreign tax credit limitation. Moreover, to the extent that industry acts in response to this incentive, high level technology and the related products will originate abroad, also, to the detriment of U.S. exports.

A day of reckoning must come because U.S. business cannot afford a total tax burden in excess of the U.S. rate and remain competitive. In contrast to the U.S., many governments, e.g., Japan, France, and the United Kingdom, assist business in their efforts to increase exports.

I would urge the Subcommittee to use its suasion in encouraging the Department of Treasury to consider the unfortunate impact of §1.861-8 that I have outlined. I would hope that the Department, upon reconsideration, would correct this potential problem before it reaps a harmful effect.

Confident that the witnesses who will appear before your Subcommittee during public hearings on the 16th will develop a variety of other areas of concern with regard to the competitiveness of high technology U.S. exports, I shall not prolong this letter in an effort to share additional suggestions, with one exception. Amidst the increasing concern which accompanies the growth of our inflation rate here at home, it should be stressed that in large part inflation springs from a low rate of productivity growth. Not only will R&D and a new technology effort serve to strengthen our nation's international competitiveness, but in turn they will function to elevate and bolster our sagging productivity.

Economic research by Edward Denison at Brookings, among others, indicates that almost one-half of the U.S. increase in productivity for the last thirty years is attributable to technological innovation. Technological change interacts with, and is embodied in, new capital goods. However, it is a distinct process and one that can often be capital-savings rather than capital-using.

Statistics in recent years have underscored the simple truth that the U.S. is consuming more as a percentage of GNP, dedicating a declining percentage of resources to R&D, and investing less. You and the Subcommittee are to be commended for devoting attention to the myriad of factors which have contributed to this unfortunate trend.

If in your further deliberations in this subject area you feel that I might be of assistance, please call upon me.

Sincerely,

John M. Walker
Senior Vice President
and Treasurer

JMW/sc

THE COMPETITIVENESS OF U.S. HIGH-TECHNOLOGY EXPORTS

Testimony prepared for
The U.S. Senate Committee on Banking, Housing and Urban Affairs
Subcommittee on International Finance

Dr. Lawrence G. Franko, May 1978*

Numerous studies have established beyond a reasonable doubt that there is a close relationship between the high levels of Research and Development (R&D) activity in certain U.S. industries, and the success of those industries in world export markets.** In general, high R&D expenditures and (what amounts to roughly the same thing) a high proportion of scientists and engineers among an industry's work force, are the hallmarks of sectors in which U.S. exports are a -- usually very large -- multiple of U.S. imports.

Any list of the U.S. manufactured products that dominate world trade in their fields is also largely a list of products in which R&D expenditures as a percentage of sales or of value added are among the highest in all U.S. industry. Aircraft,

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* Director, Project on American Policy and European Economic Interests, Carnegie Endowment for International Peace and Adjunct Professor of International Business Diplomacy, Georgetown University. Formerly Professor of International Management, Center for Education in International Management (CEI), Geneva, Switzerland, and Director for Continental Europe of the Harvard Business School Multinational Enterprise Project.

** The relevent studies include Branson, William, and Junz, Hellen, "Trends in U.S. Trade and Comparative Advantage" Brookings Papers on Economic Activity, No. 2, 1971;

Keesing, Donald B. "Labor Skills and Comparative Advantage", American Economic Review, Vol. 56, No. 2 May, 1966 pp. 249-258; and

Gruber, William, Mechta, Dileep, and Vernon, Raymond, "The R&D Factor in International Trade and Investment of United States Industries" Journal of Political Economy, No. 75, February 1967, pp. 29-37 both civil and military, scientific instruments, computers and business machines, electronics, telecommunications and other electrical equipment, and chemicals and pharmaceuticals are leaders on both lists. The nuclear power generation equipment industry, still among the leaders in R&D intensity, no longer accounts for significant U.S. exports. But many would attribute this development to changing U.S. regulatory and non-prolifera-tion policies, rather than to any major decline in technological capability relative to foreign competitors. Some observers would even count U.S. export success in agriculture as being related to R&D expenditures and activity: it has been noted that relative to other countries, U.S. agriculture is a high-technology business. Although current R&D outlays related to agriculture and agribusiness are not large, as a percentage of sales or value added, U.S. research into high-yielding crop varieties, and into fertilizer and irrigation applications, has clearly had much to do with U.S. export prowess in this area.

Unfortunately for the "bottom-line," short term, aspira-tions of both public policy and private business decision makers, the long and complex link between a change in R&D expenditures and a change in exports is poorly understood -- and therefore not easily predictable. R&D expenditures are inputs into the processes of discovery, development, and commerical introduction of novel products and processes; they are not the product and process outputs which give competitive advantage themselves. In addition, historical studies show that commercial payoffs from R&D tend to involve very long lead times before the fruits of increased expenditures are harvested in increased domestic, let alone international competitiveness.

R&D is investment in human capital, and neither the payoffs nor the timing of payoffs of such investment is calculable with the precision of, say, the returns from buying a new machine or building -- or even from spending money on an advertising campaign. Indeed, given unfavorable governmental, social, or business conditions, R&D expenditure *per se* can turn out to be quite unproductive of commercially useful innovation. (The Soviet Union and Eastern Europe have long spent amounts on R&D not greatly less than U.S. totals, yet, except in the military area, their harvest in internationally marketable innovations has been meager. This result has been attributed to a lack of market-oriented incentives, and to an excessive separation of academic and other research insitutes from the needs of enterprises.*)

The very lack of a clear, deterministic link between R&D expenditure input and new-product or new-process output, of course, makes R&D one of the first things to be sacrificed by "cost conscious", financially-oriented managements and

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* Wasowski, Stanislaw (ed.), *East-West Trade and the Technology Gap*, Praeger, N.Y., 1970.

government agencies in times of economic downturns or uncertainty, or when for other reasons firms and governments emphasize current comsumption and payouts over future returns. Moreover, because the link is not yet subject to neat mathematical specification, technology is simply left out of the economic forecasting models on which economic policy in the U.S. is based. Yet, there can be no doubt whatsoever that U.S. exports would be vastly less -- at current dollar exchange rates and with current political and foreign policy restrictions in force -- had not the U.S. led the world in R&D based innovations such as the wide-bodied jet, high-thrust jet engines, precision-guidance, the xerox copier, the computer, electronic semi-conductors, satellite communications, instant-photography, penicillin, hybrid seed-grain development, genetic breeding and so forth.

All of these innvoations were based on a good deal of "R" -- much of it not of U.S. origin -- and much more "D". Most had very long lead times before the required technical and commercial break-throughs were made. Contrary to the view that "government never does anything except 'interfere' with business", a very large proportion of these innovations -- perhaps a majority (though I am not aware of any recent tabulation) -- were nurtured by the U.S. government.

The Government Role in Fostering U.S. Comparative Advantage

The U.S. government role in nurturing U.S. high-technology of a kind which later found world markets has rarely been studied. The studies that are available, particularly the nowaging OECD "Technology Gap" series of the late 1960's strongly suggest that U.S. government support was critical not only, and perhaps even not mainly in R&D funding -- although that funding can hardly be gainsaid.* Often, successful U.S. innovations of a sort later commercialized abroad have been directly related to the U.S. government's role as an early, large, and, above all, constant and predictable customer for whatever it was that was being developed. The role the U.S. government played as a source of demand for new products and processes, and as a constant, forebearing customer in computers, semi-conductors, jet-aircraft, nuclear power generation, telecommunications, and even some pharmaceuticals and chemicals has for some reason rarely been emphasized or even recognized in most U.S. economics, business, and history textbooks. Perhaps this role of government in so strongly underpinning U.S. comparative international advantage was too embarassingly at odds with the notion that it was purely "private" enterprise that made America great. But a few histories of the great, <u>internationally</u> competitive American innovations are available,** and they show an oft-recurring

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* See McCulloch, Rachel, "Research and Development as a Determinant of U.S. International Competitiveness," unpublished TS, drafted for the Committee on the Changing International Realities, National Planning Association, March, 1978, and especially Table 4, p. 12, which details government and business R&D expenditures by industrial sector.

** See especially the OECD series on Gaps in Technology (OECD, Paris, 1969), especially <u>Computers</u> and <u>Electronic Semi-Conductors</u> See also OECD, the <u>Conditions for Success in Technological Innovation</u>, Paris, 1971.

pattern of the U.S. government setting a defense or other priority, keeping to it over a period of years, and then getting industry to target its efforts at that priority by keeping the purchases coming (and perhaps by not being <u>too</u> finicky over cost-overruns and keeping to budget as long as basic objectives were met: the point could use further investigation, but a short-term "budget" or financial mentality has often appeared harmful to innovative productivity).

The seemingly underpublicized and underappreciated role that the U.S. government has historically played in underpinning many internationally successful innovations gives special piquancy to the oft-noted dramatic decline in U.S. government-funded R&D from its heights in the late 1960's to current levels. (See Figure I for data on trends in total U.S. R&D expenditures and international comparisons. Figure I compares different countries' <u>total</u> R&D expenditures. Table I, which details <u>business</u> R&D investment, shows that R&D expenditure by the private sector has remained relatively constant as a proportion of U.S. GNP. Thus the overall U.S. decline was caused by a change in government policy.) The decline was not only <u>relative</u> to the efforts of America's commerical competitors -- as was largely the case with privately funded U.S. R&D. The decline in government funding for R&D was large and absolute. Moreover, according to some who concern themselves with the U.S. defense, health, and energy industrial bases, it was accompanied by a move from a climate of fairly predictable government demands

Figure 1

Research and Development Expenditures as a Percent of GDP

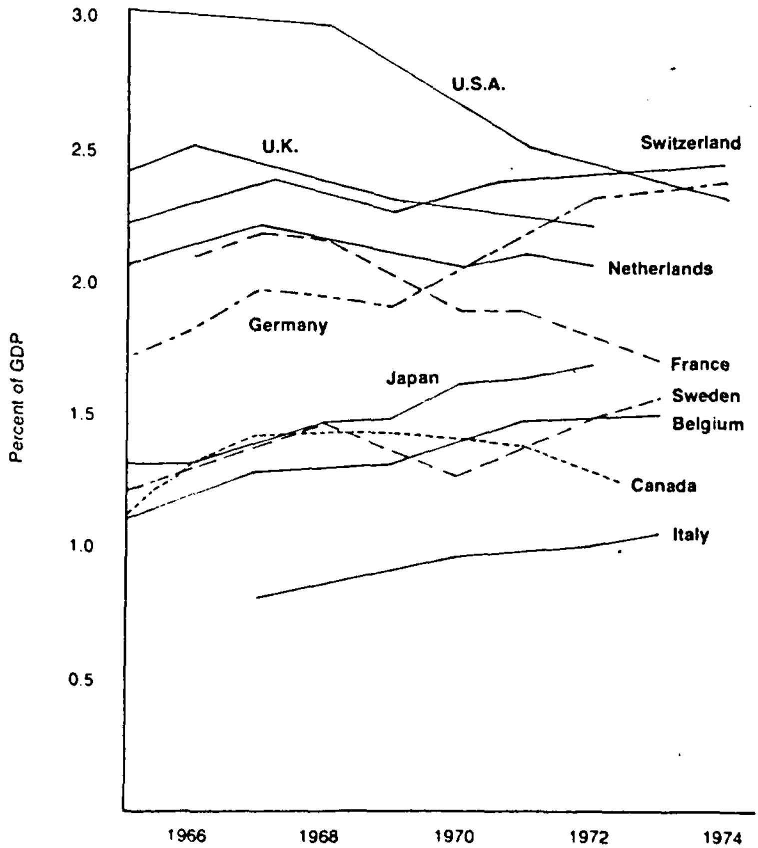

Table 1

R&D Financed by Business Enterprise
(Percent of GDP)

	1971	1972	1973	1974
Austria	0.46	0.46	0.47	0.51
Belgium	0.72	0.73	0.76	—
Canada	0.40	0.38	0.37	0.36
France	0.70	0.69	0.67	0.67
Germany	1.13	1.16	1.14	1.15
Italy	0.52	0.52	0.50	0.48
Japan	1.09	1.10	1.13	1.17
Netherlands	1.14	1.14	1.13	1.11
Sweden	0.83	0.85	0.89	0.91
Switzerland	1.98	2.00	1.99	2.00
United Kingdom	1.00	0.80	0.84	—
United States	1.00	0.97	0.97	0.97

Table based on OECD data, information furnished by the Embassies of the respective countries, and NPA estimates.

TABLE II

World Exports of Manufactures

	Britain	France	Germany	Italy	Japan	USA
1960	15.3%	9.1%	18.2%	4.8%	6.5%	22.8%
1967	11.6	8.1	18.7	6.7	9.4	20.3
1968	10.8	7.8	18.6	7.0	10.2	20.1
1969	10.7	7.8	18.7	7.0	10.7	19.3
1970	10.1	8.3	19.0	6.9	11.2	18.4
1971	10.5	8.3	19.2	6.9	12.6	17.1
1972	9.6	8.6	19.2	7.1	13.4	16.2
1973	8.8	8.5	20.0	6.1	13.1	16.4
1974	8.3	8.1	20.2	6.1	14.7	17.7
1975	8.9	9.0	18.5	6.7	14.4	19.0

Source: US Department of Commerce

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on industry to one in which procurement levels and priorities began to change with temporary shifts in political winds.

Private R&D Myopia

During the decade during which U.S. government-funded R&D was being allowed to decline, absolutely and relative to foreign countries, private R&D, at least in most sectors seemed to stay at roughly the same level of expenditure as a percentage of U.S. Gross National Product. (See Table I.) But this practice of more-or-less keeping R&D expenditures in line with the general increase in economic activity occured at a time when several other countries' private R&D activity was increasing rapidly. It was as if the U.S. private sector based its R&D investments in human capital <u>not</u> on what international competition was doing, but on a rule of thumb that said "keep R&D adequate for growth in the <u>domestic</u> economy."

One explanation for this seeming R&D myopia may be that U.S. business fell too easily for the public-relations slight-of-hand perpetrated by J.J. Servan-Schreiber when he titled his book "The American Challenge". Few seemed to notice that the process of American corporate expansion into foreign markets during the 1950's and 1960's, when it was described by serious scholars like Raymond Vernon, looked not like an American challenge but rather like a foreign "vacuum cleaner", sucking out products and processes the U.S. had developed during World War II and the Cold War that followed.* In that view, it was only to

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* Vernon, Raymond, "International Investment and International Trade in the Product Cycle," <u>Quarterly Journal of Economics</u>, Vol. 80, No. 2, May 1966; and

<u>Sovereignty at Bay</u>, Basic Books, N.Y., 1971.

be expected that the suction on U.S. exports would slacken when the rate of U.S. innovation relative to that in other countries slowed down, and when (or if) other countries' real incomes and production capabilities came to rival those of the U.S. This sequence of events has happened -- quite apart from the depressing effects on U.S. exports of any temporary cyclical effects of the differentially slower growth of foreign economies emphasized by many economists, or the cumulative effect of U.S. foreign policy restrictions on exports noted by the U.S. business press.*

But perhaps one reason why U.S. business as a whole did not respond to changing international competition-- and just focused on keeping even in R&D investment in the domestic market -- has to do with the fact that, contrary to the mythology of "the U.S. multinational enterprise", so few U.S. firms are aeriously involved in international business. it is a truism that only some 7% of all U.S. firms have ever exported and that only some 200 of the Fortune 500 largest companies can be considered "multinational", in the sense of having extensive foreign production operations.** Most U.S. business is literally flying blindfolded in a world airspace increasingly crowded with foreign competitors who, thanks to small, open, raw-materials-short domestic markets, either feel they have to keep

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* Business Week, "The Reluctant Exporter", April 10, 1978.

** Harvard Multinational Enterprise Project.

aware of foreign markets in order to survive, or have governments who urge the point on them.

However, short of U.S. government support for the establishment of Japanese-type trading companies -- an institution notably and regrettably lacking from the pantheon of American business practice -- "getting U.S. small business to export" to a degree that would amount to much in terms of the total U.S. trade balance seems unlikely. Small, domestic firms quite rightly consider foreign markets mysterious, risky, complicated places, particularly in a world of unpredictably flexible exchange rates -- that supposed _panacea_ for U.S. export ills. Some may consider the fact regrettable, but export business is big business. For that matter, so is most U.S. R&D: the National Science Foundation estimates that some 80% of all private U.S. R&D spending is undertaken by the top 200 _Fortune_ firms.

Only big business can cope on a significant scale with a world that includes a kaleidescope of exchange risks, political risks, governmental and legal controls, market differences, and divergent competitive practices -- and also satisfy the many and increasing exigencies of U.S. government foreign policies with respect to antitrust, boycott reporting, credits subject to political constraints, etc. Moreover, the history of U.S. innovations and U.S. comparative advantages in _international_ markets suggests that by the time foreign customers are significantly interested in U.S. goods, the firms will be big in the domestic market in any event. The major U.S. (and Japanese, German, French and other) exporters are, for better or worse, large firms. Their role in the sectors of particular U.S. international comparative advantage (jet engines, aircraft, computers, electronics, etc.) could not be more flagrantly at variance with the models of pure competition long held to be the ideal organization of the U.S. economy by many in the economics and anti-trust professions. Two companies produce and export virtually all U.S. jet engines; three, all U.S. large civil aircraft; a half-dozen each, most U.S. military aircraft, computers, electronics, and telecommunications products; and so on. What is good for big business may not always be good for the country, bit if we need to export to pay for our imports, big business is not always bad either.

It is true, of course, that big firms do not seem to invent or discover as many new products as small firms. And some evidence suggests that medium size firms may be best at bringing discoveries to broad domestic markets.* But if the past is any guide at all, big firms are the ones who have the financial resources, the personnel, and the imperative to grow beyond the domestic market, to tolerate the unfamiliarity of foreign operations, to cope with political and exchange risks and to make the investments in foreign distribution, service networks,

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* See Morton J. Kamien and Nancy L. Schwartz, "Market Structure and Innovation, a Survey", Journal of Economic Literature, March 1975, for a comprehensive discussion.

and product modification facilities which are essential to international success.

A "Transfer of Technology?"

Big multinational firms, to be sure, produce, and occasionally do R&D abroad. The fact that they transfer production technology abroad, or even develop some outside of the U.S., has given rise to fears that these activities substantially substitute for U.S. exports, or worse, lead to a relative gain in other countries' technological, and thence competitive abilities.

Other countries' R&D efforts, and technological skills have risen dramatically over the past decade and on half. So has their technological competitiveness, as measured either by conventional analyses of shifts in world export-market shares (which, as Table II demonstrates, show a slide for U.S. manufactures since the 1960's despite a large decline in the U.S. dollar exchange rate), or perhaps even more meaningfully in a world in which exchange rates are not held constant, as measured by world market shares of U.S. firms in their principal industries obtained from domestic sales, exports and foreign production.*

It would be an ethnocentric distortion in the extreme to imagine that "other companies in the world obtained their skills mainly because we gave our technology away, through foreign investment." The

* See: Franko, L.G. "The Future of Multinational Business," Harvard Business Review, forthcoming, September 1978.

serious work that has been done to examine the relationship between foreign direct investment in production facilities and exporting concluded that there is generally (if not invariably) a high degree of complementarity between export success and foreign investment. Investments in service facilities, distribution outlets, foreign market knowledge, assembly plants, local product modification and development facilities -- investments not always separable from foreign manufacturing -- tend to enhance U.S. (and other investing countries') export success much more often than they substitute for it.*

U.S. firms do occasionally, and perhaps increasingly undertake "R&D" abroad, but in total volume, or as a proportion of total foreign R&D activity, foreign R&D by U.S. firms has been apparently very tiny. (In Japan, the country that has most noticeably gained world market share in manufactured exports, R&D has almost invariably been undertaken by Japanese firms.)

The foreign R&D of U.S. firms -- insofar as we know much about it -- has by and large been either oriented to the kind of product modification which enhances U.S. export capabilities, or to R&D activity of a kind not going on in U.S. facilities.**

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* Thomas Horst, "American Multinationals and the U.S. Economy", American Economic Review, May 1976 and Niehans, Jurg, "Benefits of Multinational Firms for a Small Parent Economy: The Case of Switzerland", in Aginon, T. and Kindleberger, C.P., Multinationals from Samll Countries, MIT Press, Cambridge, 1977.

** Robert C. Ronstadt, "R&D Abroad: The Creation and Evolution of Foreign R&D Activities of U.S.-Based Multinational Enterprises," Harvard Business School D.B.A. Thesis, 1975.

The results of "off-shore" R&D by U.S. firms, according to recent Harvard Multinational Enterprise Project data, have, in fact, found their way from foreign laboratories into U.S. production in, at minimum, a couple of hundred cases. The Harvard Business School multinational enterprise project has, more by accident than by design, collected a large number of illustrations of "reverse" transfers of technology, by U.S. firms from their foreign subsidiaries to U.S. production. But since the main focus of the Harvard data-gathering effort was on outward U.S. technology transfer, it is thought that there are probably many more examples that could be found were study specifically focussed on this issue. In recent years, there has been a considerable inward transfer of technology by <u>foreign</u> firms setting up production in the U.S.* It is certainly the case that, in the recent past, the number of new products and processes taken from U.S. origins to foreign production sites (usually by U.S.-owned firms, but occasionally by foreign firms with foreign subsidiaries here) has been greater than the "reverse" flow. But the flow has been by no means a one way street. And very much more has happened to enhance foreign nations' and firms' competitiveness than their simply "learning the secrets of U.S. technology."

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* See Chapter VII of my book on <u>The European Multinationals</u>, Greylock Publishers, Stamford, Conn., 1976, as well as the series of papers on recent foreign investment in the U.S. currently being prepared under the auspices of the Southern Center for International Affairs, Atlanta, Georgia.

As I have pointed out elsewhere (in a forthcoming Harvard Business Review article on "The Future of Multinational Business"):

> Some of what happened was that the 1960's vintage "management-gaps" and "technology-gaps" in the U.S.'s favor were not staying equal. By the early 1970's, large non-American firms had learned how to systematically manage modern, multidivisional organizational structures -- and had perhaps improved on U.S. practice by adopting more collegial, less conflictual management styles.
>
> Continental and Japanese capabilities in product and process innovation have grown considerably relative to those of the United States (and the U.K.). Rates of growth in productivity in manufacturing in France, Germany, Italy and elsewhere on the Continent, -- and of course in Japan -- considerably outstripped those in the U.S. and the U.K. during the past two decades, particularly in manufacturing industry. The 38 large Continental firms (of 64 with extensive foreign manufacturing) in the Harvard/CEI Multinational Enterprise Project sample which provided data for 1970 were spending an average of 3.2% of their sales revenue for R&D; 90 U.S. multinationals supplying similar data for 1976 averaged 2.4% of sales, and 114 U.S. multinationals supplying data for 1974 averaged 2.6%. The percent of U.S. patents granted in the United States to foreign persons and firms has also risen markedly -- from 21 percent in 1966 to 38 percent in 1973.
>
> The most important causes of non-U.S. multinational growth, however, have had to do with the <u>kinds</u> of things non-U.S. multinationals do.
>
> Whatever else the quadrupling of oil prices did, it gave a tremendous boost to (world) demand for energy-saving products and processes -- and resource-short Europe and Japan had them first.
>
> United States' innovation has historically been very biased toward labor-saving, convenience products and processes, which are also energy and material intensive. The U.S. has often been described as a "throw-away" society. Europe and Japan rarely indulged in similar luxury. Continental Europe in particular has had to cope a lot longer than the U.S. (or the U.K.)

with scarce resources.* Similarly, the United States has just discovered pollution as a major problem. But densely populated Europe has long been coping with pollution, with waste and sewage disposal, with materials recycling, and most pertinently today, with limited and costly supplies of energy. Even after adjusting for differences in gross national product, a country like France has an economic structure which is nearly 40% less energy intensive than that of the U.S.

As the price of energy in the U.S. goes up relative to the price of labor and other inputs it should perhaps not be surprising that American customers like Amtrak or Eastern Airlines should express a sudden interest in purchasing French and Japanese energy-efficient locomotives of the French-German Airbus. Nor should it be surprising that European firms such as France's Michelin should be building large factories in the U.S. to produce such energy-saving items as radial tires, or that Germany's Robert Bosch should be manufacturing fuel-injection equipment in the U.S., or that France's Pechiney should be gaining U.S. market share because of its electricity-saving smelting of aluminum. Non-U.S. firms are also ahead (or may get ahead) of the U.S. in nuclear and other energy technologies meant to cope with resource scarcities, as well as in pollution control, recycling and conservation devices. Other resource-short nations in the less-developed world (and the non-OPEC nations are, at a minimum, short of energy) are also presenting European firms with market opportunities unthought of during the years of cheap oil.

One result of population pressures and resource scarcities in many countries has therefore been to stimulate the internationalization of non-U.S. enterprises: European and Japanese companies have served densely populated, resource-short markets at home, and they are therefore in a particularly good position to serve such markets abroad.

These _intra_-industry trends in international technological competitiveness are occurring at the level of products processes _within_ industries. As a result, they tend not to be noticed

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* For discussion and evidence, see L.G. Franko, _The European Multinationals_, Chapter II, and Davidson, William, "Patterns of Factor-Saving Innovation in the Industrialized World," _European Economic Review_, 8 (1976).

or studied much outside of particular industries until the symptoms of competitive change become acute.

Policy Implications

The very lack of clarity, and remarkably few serious studies of the precise nature of the links between R&D expenditures, either private or public, and U.S. international competitive advantage, make it difficult in good conscience to pose, much less recommend policy options. Clearly, more empirically and factually based studies of how precisely R&D activity in particular industries came eventually to result in high-technology, U.S. international comeptitive successes are sorely needed.

Conventional economic analysis has been remarkably deficient in providing policy guidance for the maintainance or monitoring of technology-based comparative advantages. The conventional economic theory of the basis of comparative advantage in international trade would have us imagine that the natural endowments which form the basis for various countries' trading patterns are immutable, and that relative prices then determine the pattern of trade. But much, indeed most, U.S. export trade in industry and in agriculture has in fact been underpinned by the more changeable stuff of human capital, R&D, and innovation. When past U.S. leads are whittled away by others' upgrading their skills (and it is clear that the U.S. cannot expect its current star export products to retain their leads forever) the economist's world of price competition will set in. As, and if that happens the very high level of U.S. wages and incomes relative to those of competing countries will be unsustainable, and, since dollar wages will not fall, the exchange rate must depreciate. Since the depreciation involves a reduction in U.S. monopolistic positions (monopoly rents in economists' jargon) it should be no surprise if the depreciation exceeds that called for by differential inflation rates.

One response that some have suggested is one of "technological protectionism", to keep "our" technology at home. This appears to be a particularly dubious course. Other countries have tried it. Indeed we ourselves have done so in the nuclear weapons area. Even with a draconian secrecy apparatus, technological protectionism has never been successful for long in keeping skills and technology from diffusing.*

Indeed, to the extent that the current non-American challenge in some traditionally "American" products and markets (e.g. mini-computers, wide-bodied aircraft, urban mass transit) is based on energy and materials saving processes and products of a kind not often innovated in a U.S. preoccupied with labor-saving and energy use, it can hardly be said to be based on "our" technology at all. In such cases, perhaps U.S. companies should be doing more R&D abroad and spending more time looking at what foreign customers want, in order to learn what others have to teach us -- despite the novelty of that experience for many firms.

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* For a fuller discussion, see "The Future of Multinational Business," op cit.

The U.S. government role in R&D, and in maintaining a climate for productive R&D and innovative effort, has clearly been of the utmost importance in the past. There is much evidence for the proposition that many internationally-competitive, high technology U.S. exports *today* are based on government funding or on strong support by government-as-customer in times past. If it is indeed the government-conditioned, long-term climate for public and private investment in R&D that counts it seems sadly likely that the decline in export competitiveness of U.S. high-technology products is not going to be reversed for long by a "quick fix" of increased tax expenditures, or increased availability of financing for exports -- much as these may help in the short run.

In particular, due to the long and relatively uncertain lead times of R&D investments, there is no reason whatsoever to think that the -- possibly short-lived -- profits occasionally provided exporters by a depreciating exchange rate, will make flexible exchange rates in and of themselves in any sense an "automatic corrective" of a U.S. failure to adequately invest in the people and skills that lead to innovation.

If something is known about what is *unlikely* to work, can anything be said about what might be done -- short of restarting the Cold War so that U.S. innovators will have a proven, government-provided target to shoot at, with government provided funds?

Increased public funding levels for R&D in areas of probable domestic *and international* social need might be one place to start, assuming the political feasibility of such a course. (Political leaders might point out that although some of today's electors might worry most about current unemployment and under-employment, or about consuming more of today's income, electors of tomorrow may pay a high price for the current underemployment and under-training of U.S. scientists, technicians and engineers.) Of course, without an R&D equivalent of war, if not a moral equivalent of war, it may be difficult or impossible to mobilize a public consensus for increased public R&D funding -- no matter how sensible might be proposals for public support of the development of alternative energy sources, or of a technological equivalent of land-grant colleges and extension services, or of R&D for urban transit or building techniques.

In the absence of increased funding, perhaps government guarantees for R&D spending in highly uncertain area of probable social benefits might help. The U.S. has an insurance agency (OPIC) aimed at reducing risks to investors willing to undertake socially useful, but high risk projects in developing countries. Could a similar principal be applied at home?

In the final analysis, long term U.S. export policy is domestic R&D and economic policy. Therefore, domestic economic policy could help by occasionally looking at more than short-term demand stabilization. It has been cogently argued that the current level of U.S. inflation combined with a non-indexed tax system is in reality obtaining increases in current consumption by "de-capitalizing" U.S. industry. Be that as it may, this state of affairs is surely discouraging new private capital investment and therefore the domestic diffusion of whatever new technologies are embodied in new machinery.

Given the past role of government-as-customer in fostering innovation -- in contrast to the recent tendency of government to become more fickle in its procurement habits -- perhaps multi-year procurement budgeting might be worthy of consideration. More constant and predictable regulation might also help: who would invest in building up R&D skills and in assembling an R&D team to develop a product or process if there was a fear that its profits might be regulated out of existence by the time the results got into production?

But perhaps the only real solutions are for government -- and the public -- to become more aware of what government has done to and <u>for</u> industry in the U.S., and for industry to realize that the practices, products, and processes that sufficed to give U.S. industry international superiority, while its competitors were temporarily put out of commission by World War II, will no longer do.

Statement to the Senate Commerce Committee Concerning International Technology Transfer and Overseas Research and Development*

(By Edwin Mansfield, University of Pennsylvania)

1. Introduction

I appreciate this opportunity to take part in these hearings. In accord with the Committee's request, my statement focuses on international technology transfer and overseas research and development. In recent years, there has been a very considerable increase in the amount of attention devoted by international trade theorists to technology and technological change. Technology is coming to play a much more significant role in explanations of the pattern of world trade, as evidenced by the work of Johnson, Vernon, Hufbauer, and others.[1] Unfortunately, however, economists have only recently begun to study international technology transfer in a serious way, and far more research is needed.

According to a recent state-of-the-art summary prepared by Piekarz, "we know that U.S. industries spending relatively high amounts on R and D are the leading industries in manufactured exports, foreign direct investment, and licensing. The limited extant research at the level of the firm has not established a relationship between research intensiveness and the share of exports in domestic sales, the ratio of foreign to domestic production, or the share of earnings from foreign licensing. We lack information about the impact of the type or recency of innovations on exports, foreign direct investment, and licensing. Also, we do not know the influence of exports, foreign direct investment, and licensing on the rate or direction of R and D and technological innovation by U.S. firms. . . . We know that U.S. foreign direct investment and licensing are channels by which foreign countries obtain technological knowledge. We do not know the mechanics, magnitude, or rate at which this technology diffuses abroad. Also, there is no information about the complementarity and substitutability among exports, foreign direct investment, and licensing as channels for technology transfer."[2]

One of the most important gaps in existing knowledge in this area relates to the effects of foreign trade on domestic innovation. In a recent paper, Stobaugh makes this point in the following terms: "Although research on this general subject of the effect of technological innovation on trade, investment, and licensing is in its infancy and deserves support, a more important relationship is the opposite casual flow: what effects do trade, foreign direct investment, and licensing have on technological innovation? A plausible hypothesis is that the possibility of a firm's exporting, making foreign investments, or selling licenses would induce it to engage in certain R and D programs that would not be economical if the U.S. market were the only one considered; thus, U.S. technological innovation would be increased and in turn U.S. economic growth would increase. In spite of the importance of this question, there seems to be a complete void in our knowledge, for I know of no empirical data either to support or deny this hypothesis."[3]

Another important gap in existing knowledge relates to the extent to which U.S. firms use various channels to transfer their technology abroad. There are several ways that a firm can transfer and exploit its technology abroad. First,

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*This statement is taken largely from a paper I gave at the National Science Foundation on May 21, 1977. Essentially the same material was presented at a lecture I gave at the University of Alabama and at Yale University. Also some of this material will appear in an article in *Portfolio,* a publication edited by the Economics Department of the University of Minnesota.

[1] G. Hufbauer, *Synthetic Materials and the Theory of International Trade*, Cambridge: Harvard University Press, 1966; H. G. Johnson, "The Efficiency and Welfare Implications of the International Corporation," in C. Kindleberger (ed. *The International Corporation*, Cambridge: M.I.T. Press, 1970; W. Gruber, D. Mehta, and R. Vernon, "The R and D Factor in International Trade and International Investment of U.S. Industries," *Journal of Political Economy*, January 1967; R. Vernon, *Sovereignty at Bay*, New York: Basic Books, 1971; and National Bureau of Economic Research, *The Technology Factor in International Trade,* New York: Columbia University Press, 1970.

[2] National Science Foundation, *The Effects of International Technology Transfers on U.S. Economy*, Washington: Government Printing Office, 1974, p. 3.

[3] R. Stobaugh, "A Summary and Assessment of Research Findings on U.S. International Transactions Involving Technology Transfers," in National Science Foundation, *The Effects of International Technology Transfers on U.S. Economy, ibid,* p. 19.

it can utilize the new technology in *foreign subsidiaries*. For example, if the new technology relates to a new product or product improvement, this new product or product improvement may be made and sold by the firm's foreign subsidiaries. Second, the firm can *export* goods and services that are based on the new technology. For example, if the new technology relates to a new product or product improvement, this new or improved product may be exported. Third, the firm can *license* the new technology to other firms, government agencies, or other organizations that utilize it abroad. Fourth, the firm can engage in *joint ventures* with other organizations, which have as an objective the utilization of the new technology abroad. As Caves, Hufbauer, Stobaugh, and others have stressed,[4] we know little about the relative importance of each of these channels for various types of technology and for various types of firms.

Still another important gap in existing knowledge relates to the overseas R and D activities of U.S.-based firms. When our present studies were begun, the only reasonably comprehensive data concerning the size of overseas R and D expenditures were the Commerce Department's data for 1966.[5] Since then, the Conference Board has published statistics concerning the size of such expenditures in 1971–72.[6] However, little or no information exists concerning more recent years or concerning expected changes in the near future. Also, we know relatively little concerning the reasons why firms carry out R and D overseas, the nature of the work carried out, and the value of this work to firms' domestic operations. Further, we know practically nothing about the minimum efficient scale for an overseas R and D laboratory in various industries, and we have relatively little comprehensive or systematic data concerning changes over time in the relative costs of performing R and D of various sorts in the United States, compared with performing them overseas. These topics have a bearing both on policy issues and on economic analysis in this area; yet they have been the subject of little or no economic research.

2. RETURNS FROM NEW TECHNOLOGY EXPLOITED ABROAD

As emphasized in the previous section, very little is known concerning the percentage of the total returns from U.S. firms' R and D projects that are expected to stem from foreign sales or foreign utilization. To help fill this gap, we obtained 1974 data on this score from a sample of 30 firms. This sample was composed of two parts, the first containing 20 firms in the fabricated metal products, machinery, instruments, chemical, textile, paper, and tire industries, the second containing 10 major chemical firms.[7] The first subsample was chosen more or less at random from major manufacturing firms in southern New England and the Middle Atlantic states. The second subsample was chosen more or less at random from major chemical firms located in the East. The firms in both subsamples tended to be rather large, and are quite representative of all large firms in their industries with regard to the percent of sales devoted to research and development. In general, the data were obtained from senior R and D executives and from officials involved with the firms' international operations.

If all kinds of R and D projects in all firms are lumped together, how important, on the average, do foreign markets or foreign utilization bulk in the expected returns from these firms' R and D projects in 1974? Although the two subsamples are entirely independent, they provide very similar answers to this question. In the chemical subsample, about 29 percent of an R and D project's returns, on the average, were expected to come from foreign sales or utilization. In the 20-firm subsample, about 34 percent of an R and D proj-

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[4] See their papers in the book cited in note 2.

[5] See U.S. Department of Commerce, *U.S. Direct Investments Abroad, 1966*, Part II: Investment Position, Financial and Operating Data, Group 2: Preliminary Report on Foreign Affiliates of U.S. Manufacturing Industries, undated. Also, the Pharmaceutical Manufacturers Association has published data on overseas R and D for some time. Unfortunately, however, these data are not entirely comparable with NSF's.

[6] The Conference Board, *Overseas Research and Development by U.S. Multinationals, 1966-75*, New York: Conference Board, 1976. Besides figures for 1971 and 1972, this report contains firms' forecasts for 1973 and 1975.

[7] For a much more detailed description of the study summarized in this and the following sections of this paper, see E. Mansfield, A. Romeo, and S. Wagner, "Foreign Trade and U.S. Research and Development," *Review of Economics and Statistics*, forthcoming.

ect's returns, on the average, were expected to come from these sources.[8] Of course, averages of this sort must be viewed with caution, because they conceal a great deal of variation and are influenced by the industrial (and other) characteristics of the sample. But they provide a reasonable starting point for the analysis.

Going a step further, we can disaggregate the results to the firm level, and see how great the interfirm variation is, and how it can be explained. In both subsamples, there is a large amount of interfirm variation: the average percentage of an R and D project's returns expected to come from foreign sales or utilization ranges from zero in some firms to 50 or 60 in other firms. Two hypotheses may help to explain these interfirm differences. First, these differences are likely to reflect the fact that some firms, because of the nature of their product lines, their history, and their management, make a much larger percent of their current sales overseas (through exports or sales of foreign subsidiaries) than do other firms. One would expect that such firms would tend to gear their R and D programs more heavily to foreign markets and utilization than other firms. Second, since more R and D-intensive industries seem to do more exporting, investing abroad, and licensing abroad than other industries, one might suspect that, holding constant the percent of a firm's current sales that come from overseas, more R and D-intensive firms may expect a higher proportion of the returns from their R and D to come from abroad. Both hypotheses fare reasonably well in both subsamples; and in the 20-firm subsample, these hypotheses can explain about 70 percent of the observed variation among firms in the average percentage of returns from R and D projects expected to come from abroad.

The very detailed data required to shed light on differences among types of R and D projects in the relative importance of foreign returns were gathered only from the 10-firm chemical subsample. The results indicate that R and D projects aimed at new products are the ones where foreign returns are expected to be most important, their average percent of returns expected to come from abroad being about 40 percent. According to executives of these firms, there are two principal reasons why the returns from products come in larger measure from abroad than the returns from processes. First, these firms are more hesitant to send overseas their process technology than their product technology, because they feel that the diffusion of process technology, once it goes abroad, is harder to control. In their view, it is much more difficult to determine whether firms are illegally imitating a process than a product. Second, they believe that their processes tend to be less transferable to other countries than products, because operating conditions, input prices, and the size of the market may be different than at home.

In recent years, considerable controversy has raged over the effects of direct investment abroad (and other channels of international technology transfer) on America's technological position. According to some observers, such investment may result in a reduction in our technological lead, since U.S. technology may be transferred from our foreign subsidiaries to our foreign competitors. However, a point that is often ignored is that, if U.S. firms could not utilize foreign subsidiaries (or transfer technology abroad in other ways), they might not carry out as much research and development, with the result that our technological position might be weakened. Some economists, like Caves and Stobaugh,[9] have recognized this point, but have cited the unfortunate fact that nothing is really known about the amount by which U.S. R and D expenditures would decline if U.S. firms could not transfer their technology to their foreign subsidiaries, or use other channels of international technology transfer. As a modest first step toward closing this gap, we asked the 30 firms in our sample to estimate how much their R and D expenditures would have changed in 1974 under two sets of circumstances: (1) that they could not utilize any new technology abroad in foreign subsidiaries, (2) that they could not utilize any new technology abroad in foreign subsidiaries, or by licensing the technology abroad, or by exporting new products or processes based on the technology, or by any other means. Although answers to hypothetical questions of this sort must be treated with a great deal of caution, the results should

[8] Note two things: First, the chemical industry here is defined to include petroleum refining and drugs. Second, the figures in the text for the 20-firm subsample are not entirely comparable with those for the chemical subsample, since the latter include only R and D expenditures in the United States, whereas the former includes overseas R and D expenditures by these firms as well. See *ibid*.

[9] See their papers in the book cited in note 2.

be of interest. Moreover, as we shall see, a comparison of these results with some earlier econometric findings suggests that, if anything, these results may be on the conservative side.

According to the firms' estimates, their R and D expenditures would have fallen significantly under each of the above sets of circumstances. Specifically, for the 20-firm subsample, the estimated reduction would have been about 15 percent if they could not utilize any new technology in foreign subsidiaries, and about 26 percent if they could not transfer any new technology abroad by any means. For the 10-firm chemical subsample, the estimated reduction in 1974 would have been about 12 percent if they could not utilize any new technology in foreign subsidiaries and about 16 percent if they could not transfer any new technology abroad by any means.[10] Thus, the results obtained from the two (quite independent) subsamples are reasonably close. Further, one can compare these results with what would be expected from an econometric model published a number of years ago.[11] This model, which was based on data for chemical and petroleum firms, indicates that a 30 percent reduction in the expected returns from these firms' R and D projects would result in a larger percentage reduction in their R and D expenditures than indicated above. Thus, since the firms in our sample estimate that about 30 percent of the expected returns from their R and D projects stem from some form of international technology transfer, it appears that, if anything, the above estimates may be on the conservative side.

3. CHANNELS OF INTERNATIONAL TECHNOLOGY TRANSFER

While the previous section of this paper indicated that many industrial R and D projects are carried out with the expectation that a considerable portion of their returns will come from abroad, no attention has been focused as yet on the channels (foreign subsidiaries, exports, licensing, joint ventures) by which these firms intend to effect these international transfers of technology. As many researchers have pointed out, very little is known about the extent to which firms of various sorts use each of these channels. For our sample of 30 firms, the percent of all R and D projects (for which foreign returns were estimated to be of substantial importance[12]) where the principal channel (in the first five years after the commercialization of the new technology) was anticipated to be of each type was as follows: foreign subsidiaries, 73 percent; exports, 15 percent; licensing, 9 percent; joint ventures, 3 percent. Thus, the results, which are much the same in the two subsamples, indicate that foreign subsidiaries are expected to be the most frequently-used channel, exports and licensing coming next, followed by joint ventures.

The great preponderance of cases where foreign subsidiaries are regarded as the principal channel during the first five years after commercialization is noteworthy, because, according to the traditional view, the first channel of international technology transfer often is exports. Only after the overseas market has been supplied for some time by exports would the new technology be transferred overseas via foreign subsidiaries, according to this view. To some extent, our results may reflect an increased tendency for new technology to be transferred directly to overseas subsidiaries, or a tendency for it to be transmitted more quickly to them (in part because more such subsidiaries already exist).[13] Such tendencies have been observed in the pharmaceutical industry, where many new drugs developed by U.S. firms have been introducd first by their subsidiaries in the United Kingdom and elsewhere.[14] Also, Baranson's study concludes that American firms in a variety of industries are more

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[10] In interpreting these figures, recall the second point in note 8.

[11] E. Mansfield, *Industrial Research and Technological Innovation*, N.Y., W. W. Norton, 1968. However, it should be emphasized that this check on the firm's estimates is very rough at best, and that (as noted in section 3) it pertains only to the estimates based on the second set of circumstances described in the previous paragraph of the text.

[12] For the chemical subsample, we specified that more than 25 percent of total returns should come from abroad, if a project is to be included. For the 20-firm subsample, we specified that more than 10 percent should come from abroad, if a project is to be included.

[13] It is interesting to note that in 1970 Vernon pointed out that the traditional model was losing some of its relevance for firms that had acquired "a global scanning capacity and a global habit of mind." Our results may indicate that, for many of the firms in our sample, this tendency toward a global outlook is well established. See R. Vernon, *Sovereignty at Bay*, *op. cit.*

[14] For example, see H. Grabowski, *Drug Regulation and Innovation*, Washington: American Enterprise Institute, 1976.

willing than in the past to send their most recently developed technology overseas.[15]

Changes over time would be expected in the principal channel by which a new technology is transferred abroad. In particular, as the technology grows older, there may be a tendency for exports to become a less important channel, since, as noted above, the innovator may supply foreign markets to a greater extent through foreign subsidiaries. Also, licensing may become more important because, as the technology becomes more widely known, foreign countries can take advantage of competition among technologically capable firms to obtain licenses, rather than accept wholly-owned subsidiaries. To see whether such tendencies exist in our sample, we obtained data of the sort described earlier in this section concerning the second, rather than the first, five years after commercialization of the new technology. In accord with these hypotheses, the results suggest that licensing is more important, and exports are less important, in the second five years than in the first.

It is also important to recognize that firms differ greatly in the extent to which they rely on each of these channels. Larger firms in our sample tend to rely more heavily on foreign subsidiaries than smaller firms, which would be expected since larger firms are more likely to already have such facilities abroad and to be in a position to obtain the capital required to establish new ones. On the other hand, smaller firms tend to rely more heavily than larger firms on exports. Although there has been some speculation that (holding constant size of firm) high-technology firms may rely on a somewhat different mix of channels than low-technology firms, we could find no statistically significant evidence that this is the case.

Finally, it frequently is possible for a firm to substitute one channel of international technology transfer for another. Thus, if foreign subsidiaries could not be used for this purpose, licensing or exports or joint ventures might be used instead. However, in many cases, these other channels do not seem to be very good substitutes for foreign subsidiaries, in the eyes of the firms. If they could not use foreign subsidiaries as a channel, they estimate that they would reduce their R and D expenditures by about 12-15 percent, on the average. (Recall the last paragraph of the previous section.) However, whereas it was possible for us to check the other estimates of this sort against the results of an econometric model, this was not possible for these estimates, since no relevant econometric model exists (to my knowledge).

4. OVERSEAS R AND D: EXTENT AND NATURE OF EXPENDITURES

It is well known that the overseas research and development activities of U.S.-based firms have become the focus of controversy. Some observers view such activities with suspicion, since they regard them as a device to "export" R and D jobs, or as a channel through which American technology may seep out of actual or potential competitors.[16] Others, particularly the governments of many developing (and some developed) countries, view them as highly desirable activities that will help to stimulate indigenous R and D in these countries. Indeed, the United Nations Group of Eminent Persons recommended that host countries require multinational corporations to contribute toward innovation of appropriate kinds, and to encourage them to do such R and D in their overseas affiliates.[17] Although the amount of controversy in this area might lead one to believe that the overseas R and D activities of U.S.-based firms have been studied quite thoroughly, this is far from the case. As pointed out in section 5, the unfortunate truth is that economists have devoted little or no attention to even the most basic questions concerning these activities.

As a first step toward studying these questions, we constructed a sample of 55 major manufacturing firms, this sample being divided into two parts. The first subsample, composed of 35 firms, was chosen from Fortune's 500. The second subsample composed of 20 firms, was chosen from among major manufacturing firms in the southern New England and the Middle Atlantic states. Strictly speaking, neither subsample was randomly chosen, since some firms that were asked to cooperate refused to do so. Moreover, each of the subsamples

[15] J. Baranson, "Technology Transfer: Effects on U.S. Competitiveness and Employment," paper prepared for the U.S. Department of Labor, 1976.

[16] For discussions of this point of view, see Conference Board, *op. cit.;* and E. David, "Technology Export and National Goals," *Research Management,* January 1974.

[17] United Nations, *The Impact of Multinational Corporations on Development and on International Relations,* New York, 1974, p. 70.

concentrated heavily on a relatively few industries—chemicals, petroleum, electrical equipment, and metals and machinery in the first subsample; chemicals, fabricated metal products, and instruments in the second subsample. However, a comparison of the sample with the benchmark figures provided by the Commerce Department for 1966 and by the Conference Board for 1971–72 indicates that the sample is reasonably representative of all U.S. manufacturing with regard to the average percent of R and D expenditures carried out overseas.[18]

Based on data obtained from each of these firms, it appears that about 10 percent of their total company-financed R and D expenditures were carried out overseas in 1974. During the 1960s and early 1970s, this percentage grew substantially; and they estimate that this growth will continue, but at a reduced rate, during the rest of the 1970s. By 1980, they estimate that about 12 percent of their R and D expenditures will be made overseas. Because of the importance in the innovation process of close cooperation and communication among R and D, marketing, production, and top management, location theorists like Vernon[19] have argued that a firm's R and D activities will tend to be centralized near its headquarters. Why then do these U.S.-based firms spend over 10 percent of their R and D dollars overseas? There are a variety of possible reasons, such as the presence of environmental conditions abroad that cannot easily be matched at home, the desirability of doing R and D aimed at the special design needs of overseas markets, the availability and lower cost of skills and talents that are less readily available or more expensive at home, and the greater opportunity to monitor what is going on in relevant scientific and technical fields abroad. In our sample, practically all of the firms that do any R and D overseas said that the principal reason is to respond to the special design needs of overseas markets. In their view, there are great advantages in doing R and D of this sort in close contact with the relevant overseas markets and manufacturing units of the firm.

In each subsample, there are enormous differences among firms in the percent of their R and D expenditures that are made overseas: in 1974, some firms spent nothing overseas, whereas others spent 30 or 40 percent of their total R and D expenditures overseas. To explain these interfirm differences, we constructed a simple econometric model in which the explanatory variables are the percent of the firm's sales that come from abroad, the size of its annual sales, and a dummy variable indicating whether or not the firm is in the pharmaceutical industry. This model can explain about half of the observed interfirm variation in the percentage of R and D expenditures made abroad. As would be expected, this percentage is directly related to the percent of a firm's sales that come from abroad and to the size of the firm's annual sales. Holding these other factors constant, this percentage is significantly higher among pharmaceutical firms, which seem to be affected particularly by regulatory considerations,[20] than among other firms in our sample.

Based on information obtained from the firms in our sample, the R and D they do overseas tends to be predominantly development rather than research, and aimed at product and process improvements rather than at new products or processes. Further, this emphasis on development projects aimed at rather minor changes seems to be more pronounced in their overseas than in their domestic R and D, which in part reflects the fact that much overseas R and D has as its primary purpose the modification of U.S. products and processes to suit foreign markets and conditions. Firms seem to differ considerably in the extent to which they have integrated their overseas R and D with their domestic R and D. Some firms, such as IBM, seem to have integrated their R and D activities on a world-wide basis. (Thus, IBM, when it developed the 360 series, gave each laboratory, whether at home or abroad, a specific mission. For example, the smaller machine came from Germany and the medium-sized machine was designed in England.[21]) Such world-wide integration exists in

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[18] For a much more detailed description of the study summarized in this and the following sections of this paper, see E. Mansfield, D. Teece, and A. Romeo, "Overseas Research and Development by U.S.-Based Firms," University of Pennsylvania, 1977.

[19] R. Vernon, "The Location of Economic Activity," in J. Dunning (ed.), *Economic Analysis and the Multinational Enterprise*, London: George Allen and Unwin, 1974.

[20] See Grabowski, *op. cit.;* and the references cited there.

[21] See R. Ronstadt, "R and D Abroad: The Creation and Evolution of Foreign R and D Activities of U.S.-Based Multinational Enterprises," D.B.A. thesis, Harvard, 1975; and E. Mansfield, "Technology and Technological Change," in J. Dunning (ed), *Economic Analysis and the Multinational Enterprise*, London: George Allen and Unwin, 1974.

about 45 percent of the firms in our sample that do any overseas R and D, according to the firms. On the other hand, 16 percent say that they attempt no such integration, and the rest say some limited integration is attempted.

Of how much value are overseas R and D to a firm's U.S. operations? Policy makers should be interested in this question because it must be considered in any full evaluation of the effects of overseas R and D (and foreign direct investment) on America's technological position vis-a-vis other countries. As Caves has put it, "To what extent have subsidiaries generated or acquired technologies for transmission back to their American parents . . .?"[22] Unfortunately, practically no evidence exists on this score. To shed a modest amount of light on this question, we obtained estimates from the firms in our sample concerning the percent of their 1975 overseas R and D expenditures with no commercial applicability to their U.S. operations. Their estimates indicate that, on the average, about one-third of these firms' overseas R and D expenditures have no such applicability. Also, we asked each firm to estimate the amount that it would have to spend on R and D in the United States to get results of equivalent value to its U.S. operations as a dollar spent on R and D overseas. The results indicate that, on the average, a dollar's worth of overseas R and D seems to result in benefits to these firms' domestic operations that are equivalent to about 50 cents of R and D carried out in the United States. Needless to say, these estimates are not precise, and should be viewed only as rough guidelines.

5. OVERSEAS R AND D: ECONOMIES OF SCALE AND RELATIVE COSTS

As noted in the previous section, many governments, particularly of developing countries, favor the establishment in their nations of overseas R and D laboratories by U.S.-based firms. One factor influencing the practicality of establishing a laboratory of a certain type in a particular location is the extent of economies of scale in such laboratories. If the minimum economic scale for laboratories of this sort is quite large, a firm may find it harder than otherwise would be the case to justify the establishment of such a laboratory. Despite the fact that data concerning the minimum economic scale of R and D laboratories of various types would be of value to many kinds of microeconomic studies, practically no information is available on this score. To help promote a better understanding of this topic, we asked the members of the 35-firm subsample to estimate the annual R and D expenditures of a laboratory of minimum economic scale. Although these estimates should be treated with caution, they should be of interest, since they seem to be the first systematic evidence on this topic.

The results indicate that the minimum economic scale tends to be quite substantial in most of the industries included in the sample. On the average, for a single product line, it was estimated that the expenditure per year for an R and D facility of minimum economic scale would be about $1 million in pharmaceuticals and glass, about $2 million in electrical equipment and petroleum, and about $5 million in chemicals. However, the minimum economic scale seems to vary considerably, depending on the responsibilities of the laboratory. It is less for a laboratory that performs either research or development than for one that performs both, and is less for a laboratory that deals with a single product line than for one that deals with several product lines. For a laboratory that is concerned entirely with minor product changes, the average estimated expenditure per year for an R and D facility of minimum economic scale is only about $500,000 per year—and in some industries it is substantially less. In interpreting these results, the dispersion among the estimates are perhaps as interesting as the averages. The estimates in each industry vary enormously, reflecting the fact that the minimum economic scale of an R and D laboratory depends on the specific type of work to be done, as well as the fact that opinions differ on this score even among experts.

Previous studies have indicated that one major reason why U.S.-based firms have carried out R and D overseas is that costs have tended to be lower there than in the United States. However, very little information has been published concerning the extent of this cost differential, and how it has varied over time.[23] To help fill this gap, we obtained data from the firms in the 35-firm

[22] R. Caves, "Effect of International Technology Transfers on the U.S. Economy," in National Science Foundation, *op. cit.*, p. 38.

[23] The Conference Board, *op. cit.*, has provided data comparing the average R&D salary paid by foreign subsidiaries to those paid in the United States in 1972. The results are quite similar to those found below for 1970.

sample concerning the ratio of the cost of R and D inputs in Europe, Japan, and Canada to those in the United States in 1965, 1970 and 1975. The results indicate that there was a very substantial cost differential in 1965: on the average, the cost of R and D inputs seemed to be about 30 percent lower in Europe, 20 percent lower in Canada, and 40 percent lower in Japan than in the United States. And although there was some increase in R and D costs relative to those in the United States during 1965–70, the cost differential remained quite substantial in 1970.

However, between 1970 and 1975, the situation changed drastically. Due in part to the depreciation of the dollar relative to other currencies between 1970 and 1975, the cost differential was largely eliminated for many firms. On the average, the cost of R and D inputs was estimated to be about 10 percent lower in Japan, and about 5 percent lower in Europe and Canada, than in the United States in 1975. Of course, this helps to explain the fact (noted in the previous section) that the percentage of R and D carried out overseas is expected to increase less rapidly between 1974 and 1980 than in the period prior to 1974. Since the cost differential between overseas and domestic R and D has decreased, it is quite understandable that this percentage is growing less rapidly than in earlier years.[24] Finally, note that these forecasts to 1980 were made prior to the adoption by the Treasury of Regulation 1.861–8. According to some observers, this new tax regulation may encourage increased overseas R and D by U.S.-based firms.

6. CONCLUSIONS

This paper has summarized a variety of empirical findings, many of which have implications for public and/or private policy. In the remaining space, I can indicate only a few of these implications. First, our results do not support the suggestion of some economists that firms base their R and D decisions solely on the basis of expected domestic returns. On the contrary, according to the firms in our sample, about 30 percent of the anticipated returns from their R and D projects, on the average, was expected to come from foreign sources. Based on expected domestic returns alone, these firms estimate that they would spend about 20 percent less on R and D than at present. Of course, these results do not contradict the hypothesis that firms sometimes pay less attention to foreign markets than to those at home. But they do indicate that, although there may be a tendency to emphasize domestic markets, this tendency is not so strong that public policy can assume that decreased opportunities for international technology transfer would have little or no effect on U.S. R and D expenditures. On the contrary, although such measures would not result in enormous cuts in percentage terms, they apparently would prompt a perceptible and significant reduction in R and D expenditure, which would in turn weaken our own technological position.

Second, our results have implications for the current controversies over the channels of international technology transfer. Even in the first five years after the commercialization of the new technology, foreign subsidiaries, rather than exports, licensing, or joint ventures, are expected to be the principal channel for the majority of these firms' projects. In part, this is due to the fact that the firms in our sample tend to be large, and perhaps to the industrial composition of the sample. Without question, it frequently is possible for a firm to substitute one channel of international technology transfer for another. Thus, if foreign subsidiaries could not be used, licensing or exports or joint ventures might be used instead. However, in many cases, these other channels do not seem to be very good substitutes for foreign subsidiaries, in the eyes of the firms. If they could not use foreign subsidiaries as a channel, they estimate that they would reduce their R and D expenditures by about 12–15 percent, on the average. However, whereas it was possible for us to check the estimates in the previous paragraph against the results of an econometric model, this was not possible for these estimates, since no relevant econometric model exists (to our knowledge).

Third, our results provide evidence concerning the importance of overseas R and D expenditures by U.S.-based firms. When compared with the total R and D expenditures in various host countries, their size is particularly striking.

[24] If very significant differences exist between the productivity of U.S. and overseas R and D personnel, they could offset, wholy or in part, the observed differences in the relative cost of R and D inputs. But the bulk of the firms in our sample seem to feel that R and D personnel in Europe, Japan, and Canada are no less productive than those in the United States, so this factor cannot offset the observed differences in the relative cost of R and D inputs in the great majority of cases.

In the early 1970's, about one-half of the industrial R and D performed in Canada and about one-seventh of the industrial R and D performed in the United Kingdom and West Germany was done by U.S.-based firms.

Fourth, the firms in our sample estimate that, on the average, each dollar of overseas R and D is of as much value to their U.S. operations as about 50 cents of domestic R and D. This result, although very crude, is of some relevance to the debate over the effects of direct foreign investment by U.S.-based firms on the U.S. technological position vis-a-vis other countries. As our econometric results show, there is a very close relationship between the extent of a firm's foreign subsidiaries and the extent of its overseas R and D. To the extent that some overseas R and D is carried out only because of prior foreign investment, such benefits may represent a positive effect of direct foreign investment on the U.S. technological position.

Fifth, the rate of technological change in various industries and firms depends on the amount of efficiency of their overseas R and D expenditures, as well as their R and D expenditures in the United States. Unfortunately, this fact is not recognized in any of the econometric studies carried out to estimate the effects of R and D on U.S. productivity growth. All of these studies confine their attention to R and D expenditures carried out in the United States, in part because this is all that is included in the official R and D statistics. For well-known reasons, the resulting errors in the independent variables in these regressions may lead to biases in the regression coefficients, particularly in more recent years when overseas R and D expenditures have been relatively large.

In conclusion, it should be stressed that our findings are subject to a variety of limitations. For one thing, the results pertain to a sample of 30 firms (in sections 2 and 3) and of 55 firms (in sections 4 and 5). For another, some of the data obtained from the firms were necessarily rough. A detailed account of the limitations is contained in my technical papers cited in notes 7 and 18. No pretense is made that the studies described here are close to the last word on these subjects. On the contrary, they must be regarded as tentative, for many reasons given in the technical papers. Nonetheless, we believe that these studies provide some of the first pieces of empirical evidence bearing on a number of aspects of international technology transfer of importance to policy makers.

EXPORT-IMPORT BANK OF THE UNITED STATES
WASHINGTON, D.C. 20571

BOARD OF DIRECTORS

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April 28, 1978

Mr. Robert W. Russell
Counsel, Subcommittee on International Finance
Committee on Banking, Housing & Urban Affairs
5300 Dirksen Senate Office Building
Washington, D. C. 20510

Dear Bob:

I am sorry that it will not be possible for me, as I explained to you on the telephone the other day, to testify at the joint hearing of the Subcommittee on International Finance and the Subcommittee on Science, Technology and Space on May 16. I will be in Europe at that time on Eximbank business.

With respect to the immediate questions you will be considering on that date, I recommend to you the data which Special Systems and Product Group of Fairfield, Connecticut, developed for GE. One of these papers is entitled "The Role of High-Technology Industries in Economic Growth" and the other is entitled "The Impact of Research and Development on Long-term Economic Growth". If you wish I can send my copy on to you but GE can undoubtedly send you a set directly.

It seems clear that the U.S. must become increasingly an exporter of high technology products and that every effort must be made to encourage these relatively new and highly innovative companies to get into the export markets as quickly as possible. As you know, the companies continuing to sell products developed years ago have a tendency to maintain their competitive position by instituting stringent cost controls which often mean reduced employment in favor of further automation. Companies, generally small, engaged in the production of new high technology products on the contrary, are those which have little reason to control costs and are therefore much more likely to add to employment in excess of their growth trends. I am enclosing a brief study in this connection prepared by the President and Treasurer of the M.I.T. Development Foundation, Inc., which you may find interesting.

I will look forward when I get back to continuing my work on the trading company concept which you and I have discussed in the past, and on which I am now gathering data. It does seem extraordinary to me that we find ourselves financing exports of American goods through the local offices of Japanese trading companies. There must be a way of encouraging the formation of U.S. trading companies which will have offices abroad and which will concentrate on developing new markets for small and medium sized companies which would not have the marketing strength to do this on their own. As I go along on this project, I will certainly keep you posted on any interesting data that is developed.

I have greatly enjoyed working with you and look forward to doing so in the future.

With best regards.

Sincerely,

Thibaut

Thibaut de Saint Phalle

Enclosure

THE ROLE OF NEW TECHNICAL ENTERPRISES IN THE U.S. ECONOMY

by John O. Flender & Richard S. Morse

Many factors -- domestic and world-wide -- influence the U.S. economy and employment. Because of the increasing cost of imported energy, declining supply of domestic natural resources, and competition from goods manufactured abroad with low cost labor, the U.S. must rely more heavily on the export of high technology products in order to maintain a high level of employment and a favorable balance of payments. Technology does play a very important role in the maintenance of a sound domestic economy, the enhancement of productivity, and our ability to compete in the world marketplace. Against this background, it is important to review the current environment for technological innovation in the United States.

Many foreign countries recognize the importance of maintaining a healthy climate for technical innovation and have taken positive steps, particularly in the support of new product development, to encourage the innovative process. This country unfortunately has no effective spokesman for either the entrepreneur or new enterprise generation. Congress has historically shown an increasing lack of understanding of the innovative process, the need for incentives for the entrepreneurs, the venture capitalist, and the role of new technical enterprises in the U.S. economy.

While mechanisms for more effective applications of science, technology, and innovative management, represent a general requirement of both large and small companies, the "new technical enterprise" has made a unique contribution to the American economy. The environment for a new generation of "technical enterprises" to become a future Texas Instruments, Xerox, or Polaroid appears to have deteriorated significantly in recent years.

In 1967 the Technical Advisory Board of the U.S. Commerce Department studied and reported on technical innovation.(1) One important fact came to light, namely, that the rate of sales growth and job creation occurs more rapidly in the innovative high technology companies than it does in the more mature organizations. The data for those relatively new innovative companies shown in the 1967 report has been revised to cover the period 1945 - 1974 and appears below. For comparative purposes, data for the same period for selected mature companies from a variety of industries is also shown.

Messrs. Morse and Flender are President and Treasurer respectively of the M.I.T. Development Foundation, Inc.

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(1) Technological Innovation: Its Environment and Management, U.S. Department of Commerce (Washington, D.C.: Government Printing Office, 1967).

Average Annual Growth (Compounded)[2]
1945-1974

Innovative Companies	Sales	Jobs
Polaroid	14.0%	9.0%
3M	14.1%	9.0%
IBM	16.8%	10.2%
Xerox	24.2%	19.4%
Texas Instruments (1953-1974)	21.2%	17.3%
Weighted Average	16.5%	10.8%

Mature Companies	Sales	Jobs
Bethlehem Steel	4.9%	-1.7%
DuPont	8.6%	2.6%
General Electric	8.4%	3.5%
General Foods	8.2%	4.5%
International Paper	9.2%	2.8%
Proctor & Gamble	9.6%	3.8%
Weighted Average	7.8%	1.9%

The above data covers the 29 year period from 1945 through 1974. Over the short 5 year period 1969 through 1974, young, high technology companies have shown a far more spectacular growth rate.

Average Annual Growth (Compounded)[2]
1969-1974

Date Incorp.	Young High Technology Companies		
1968	Data General	140.5%	82.5%
1959	National Semiconductor	54.3%	59.4%
1960	Compugraphic	50.2%	24.0%
1957	Digital Equipment	36.8%	30.7%
1964	Marion Labs	24.5%	25.4%
	Weighted Average	42.5%	40.7%

[2] Moody's Industrial Manual, Moody's Investors Services, Inc., New York, New York

During the five-year period 1969-1974, the average per cent annual growth of the companies in each of the above three groups was:

	Sales	Jobs
Innovative Companies	13.2%	4.3%
Mature Companies	11.4%	0.6%
Young High Technology Companies	42.5%	40.7%

Although complete data is appended, it is worth noting here that during the five-year period the six mature companies with combined sales of $36 billion in 1974 experienced a net gain of only 25,000 jobs, whereas the five young, high technology companies with combined sales of only $857 million had a net increase in employment of almost 35,000 jobs. The five innovative companies with combined sales of $21 billion during the same period created 106,000 new jobs.

It would appear that our more mature large corporations tend to reduce employment via such mechanisms as improved productivity. The technically based new enterprise has the ability to create new job opportunities and products which are competitive in the world markets. It is suggested that the concept of innovation within the large corporation is viewed in terms of cost reduction and increased productivity in an effort to remain competitive. In the small new technically based enterprise innovation is a way of life and is responsible for the creation of new products, processes and job opportunities.

The foregoing data, while in no way a statistical study of different groups of companies, does nevertheless, indicate trends in the business community and does point to the importance of new innovative companies in the development and commercialization of new technology.

The business environment which led to the growth of companies like IBM, 3M, Polaroid, Texas Instruments, and Xerox in the post World War II years, and which encouraged the establishment of Digital Equipment, National Semiconductor, and other high technology companies in the 1950s and 1960s was a favorable one. Entrepreneurs were plentiful and enthusiastic. They were encouraged by economic incentives and by the freedom of the system which allowed them to function and to be creative without the constraints of large corporations. Government research and development funds were available to small companies, and more than a few enterpreneurs built successful businesses on DOD and NASA contracts which provided the basis for commercial products. Capital was attainable, either from established venture capital sources, invididual investors or through the sale of securities to the public.

In the late 1960s and early 1970s changes took place in the environment for the establishment of new high technology enterprises. This resulted in a reduction in the rate at which new companies were started and restricted the development of many of the small companies which were established during the period. These changes appear to fall in the following areas:

Government Funding of Research and Development. About five years ago a growing disenchantment with science and technology began to develop in this country as a result of ever increasing government spending for R&D without, what many people believed, were benefits which justified the expense. The level of government financed R&D (in constant dollars) began to decline. Other measures, particularly the adoption of the Mansfield Amendment, tended to restrict DOD funding of R&D to specific goal-oriented tasks and to limit the programs which might have important commercial significance.

Both small companies and universities were directly affected by these cutbacks, but there was also an indirect effect which was much less obvious. Not only were government R&D contracts no longer a mechanism for small companies to get started, but government-sponsored university research was so oriented that opportunities for the establishment of new companies to commercialize new technologies were greatly reduced. (The RANN -- Research Applied to National Needs -- Program of the National Science Foundation may be an exception to this generalization.)

Another change related to government funding of R&D has been the reduction in acceptance of unsolicited and of sole source proposals in favor of competitive bidding for R&D procurement. Although not generally understood, the unsolicited proposal has played a unique role in the development of innovative technologies by providing relatively small amounts of money to bring a new concept or technology to the point where a product might emerge. Now an unsolicited proposal may provide the basis for a request for additional proposals and competitive bidding. The practice of competitive bidding tends to favor the large corporation which has the ability to submit and resubmit detailed and costly proposals to fit the requirements of a particular situation.

Contract administration of government programs also has become overwhelmingly burdensome and often, particularly in small companies, the monitoring and reporting requirements have grown all out of proportion to the size of the task.

Financial Incentives. At the same time the government was under pressure to reduce spending for research and development, the long establishished practice of granting stock options came under attack. It was felt by many, and not without some justification, that there were an increasing number of abuses of the stock option programs in large corporations. As a result, the rules governing the granting and tax treatment of qualified stock options were tightened. Abuses in the large corporations were to some extent curbed, but the unique incentives previously offered by stock options to the entrepreneur were essentially eliminated.

Income taxes have now been adjusted so that salaries and wages became taxable by the Federal Government at a maximum rate of 50% while capital gains taxes have increased from the maximum of 25% to a maximum of 35%. Simultaneously, more and more states have levied new income taxes or increased old ones. In some states considerably higher rates are applied to unearned income and to capital gains than are applied to salaries and wages. The result has been a significant narrowing of the gap between income tax and capital gains tax rates and the corresponding reduction in the financial incentives for the entrepreneur. As a result of the changes in the tax structure and in the stock option rules, the entrepreneur now finds that the potential "after tax" gain from starting his own company may not be commensurate with the risks, and that employment by a large company at a relatively high salary may have greater overall attraction.

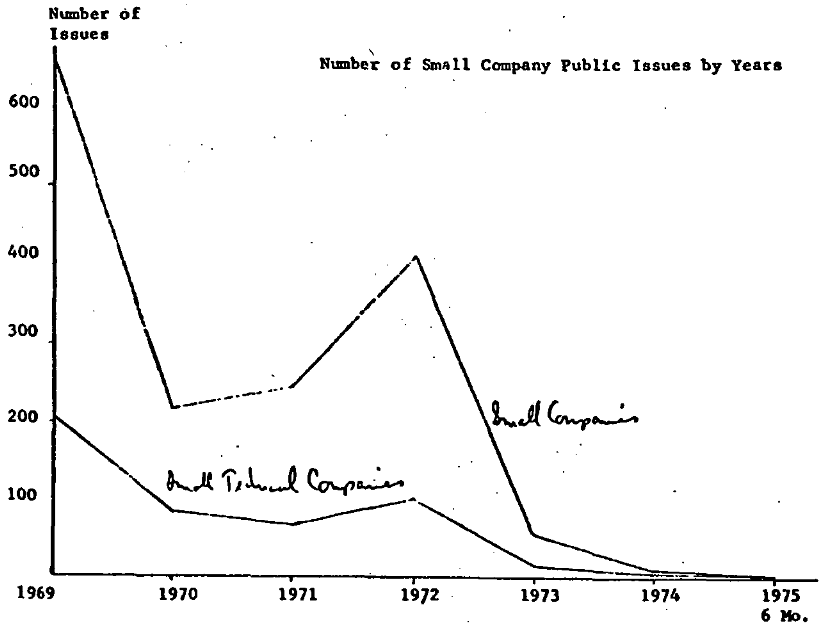
Regulatory Environment. During the last five years, the role of the government regulatory agencies has been an ever increasing one. Environmental requirements, the need for impact statements for new activities, safety and health regulations, etc.; at all levels of government have changed the business climate for both large and small companies. Sometimes the small company can operate more freely than the large company within this new climate, but when conformity is required, the small entrepreneur is less well equipped both financially and with respect to manpower than the large organization.

The direct cost of conforming with specific new regulatory requirements is easily identified, but what about the indirect costs to the small company which have resulted from compliance with the expanded requirements of the established regulatory agencies? Consider the Securities and Exchange Commission. One of the leading national auditing firms estimated recently that in the last five years, the requirements for a Form S-1 registration have been expended to the point where an equivalent registration statement today would take two and a half times the number of man hours it would have required five years ago. The resulting increase in cost combined with the effect of inflation has made registration prohibitively expensive for the small company. Furthermore, expanded reporting requirements are now so onerous and expensive that many small publicly held companies are looking for ways to reduce their number of stockholders to a point below which reporting will no longer be required.

Reduction of Liquidity. In recent years, many professional investors have been discouraged from providing seed capital to new companies because of concerns about liquidating their investments in a reasonable time period. Three factors have contributed to the reduction in liquidity; first, the cost of "going public" has for many companies become prohibitively expensive; second, the public, as a result of bad experiences, is unwilling to invest in speculative securities; and third, SEC regulations significally restrict the large stockholder from disposing of his securities in a reasonably short period of time. The SEC's new Rule 144 has been beneficial to investors by clarifying a number of unanswered questions regarding the resale of unregistered securities when a public market exists. The problem is that in the absence of an established market, Rule 144 does not apply. For many years, the SEC has been promising a Secondary Private Placement Rule, but the rule has not been forthcoming. At the present time, there is no way a large investor can liquidate a significant portion of his holdings in a private transaction without running the risk of being in violation of the Securities Act.

Reporting Procedures and Public Disclosures. In recent years the SEC has pushed for more prompt and detailed disclosure of matters pertaining to the business of a so-called "Reporting Company". The result has been a staggering increase in legal and auditing costs as well as in the nonproductive work load. Small companies have been particularly hard hit by these requirements which take a disproportionately large percentage of overhead effort and executive time.

<u>Capital Supply</u>. Probably the most important change in the environment for starting and developing new high technology companies during the period has been the decline in the supply of risk capital for small companies. Not only has the supply contracted, but there appears to have been a shift away from investment in technical companies. Small new public issues in the U.S. by companies with a net worth of less than $5 million before the offering declined from $1.1 <u>billion</u> in 1969 to only $16 <u>million</u> in 1974. But what is more disturbing is the fact that the percentage of dollars invested in technical companies included within the group of small companies described above, declined from an average of 33% in 1969 and 1970 to an average of only 23% in the years 1971 through 1974. It should also be noted that there have been no public financings of Small Technical Companies of the type described between March of 1974 and August 1, 1975.



Note: See Appendix B for complete data and source.

In late 1974, a survey was made of the members of the National Venture Capital Association (NVCA) regarding the number and amount of private financings concluded during a period of approximately 5 years. Fifty seven firms or 71% of the membership responded to this survey as tabulated below:(4)

	No. of Venture Capital Firms Involved in New Financings	Number of New Financings	$ Value of Financings (Millions)
1970	39	223	$66.4
1971	48	225	84.5
1972	47	223	89.8
1973	46	185	93.5
1974 (nine months)	37	93	47.8

The statistics indicate a distinct decline in venture capital investments in new projects during the period 1973 through 1974. Although the 1974 data is for a 9 month period and may not be indicative of the level of activity during the entire year, NVCA officials indicate that there were very few financings during the last quarter of 1974. The opinion is substantiated by the public issues data, taken from Venture Capital.

Unfortunately, data regarding the financings of technical "start-up" situations and very new companies is almost non-existent; first, because the sources of early stage venture capital have been both varied and diverse and, second, because most independent, as well as organized investors, are reluctant to discuss their activities. The NVCA data does not show, nor was it intended to show, the nature of the investments or the stage in a company's development during which a financing was completed. Information gathered independently from within the venture capital community, however, suggests that recent financings involved relatively conservative investments in seasoned companies as contrasted with the more speculative, early stage investments made at the start of the five-year period. There is sufficient information in the NVCA study to support this contention.

If, as indicated by the NVCA data, the number of private venture capital financings is declining, the question can quite naturally be raised, "Is there unused capital available?" The survey indicated that about 22% of the capital of those groups who responded was in cash, but went on to say, "Since most venture firms tend to hold cash reserves for contingencies, it would appear the venture industry is currently rather fully invested."

Both the public issues data and the private financings data reflects the declining number of financings by clearly identifiable segments of the financial community. There is no data regarding the individual and truly private source of seed money. One possible, but as yet unproven, source of venture capital may come from corporate groups which are interested in diversification and the development of windows on new technologies through the acquisition of minority interest in small companies.

(4) Survey of Venture Capital Industry and Its Impact on Public Companies Financed, prepared for the National Venture Capital Association by Aharon R. Ofer, Asst. Prof. of Finance, Northwestern University.

The most serious shortage of capital has been experienced by those individuals and organizations looking for seed money or "start-up" capital. Investors, who were always ready to provide limited funds to a brand new enterprise which appealed to them, now shun a "start-up" situation. First, start-ups require far more money than was needed five to eight years ago. Higher costs have resulted from inflation, increased regulation of business and the absence of government R&D to expedite the initiation of technologically based companies. Second, because of the current economic environment, investors have tended to put money into more seasoned companies where markets are known, management teams have been developed, and investment can be made in the form of an interest bearing note with warrants or other debt plus equity arrangements. Start-up ventures should be considered solely as equity investments usually in unproven market areas with untried management teams. Third, the venture capitalist is no longer able to leverage his investment in a new enterprise with bank debt after a new company begins to make sales. This type of money is extremely difficult to find and if such loans are made, personal guarantees of officers and directors are usually required.

Considering the problems of venture capital today, it is remarkable that any new companies have been started and financed in the last three years.

CONCLUSIONS

As observed in the 1967 CTAB report on technological innovation, the entrepreneurial process, particularly as it relates to high technology companies, is not well understood. It has been noted, however, that the process can occur only in a favorable environment. This environment has deteriorated over the last few years in the following manner:

1. Government R&D programs are a less significant factor in stimulating high technology companies. The character and complexity of government procurement policy and procedures and management methods has deteriorated significantly.

2. Financial incentives for the entrepreneur and the investor have declined.

3. Government regulation has greatly increased the operating cost and management problems of new business enterprises.

4. The liquidity of investments in small companies has been reduced by the absence of a receptive public market and by regulation.

5. The supply of capital for starting new high technology ventures is almost non-existent. Private capital for seasoned new companies is difficult to obtain and public financing is essentially unavailable.

These changes in the entrepreneurial environment present a serious problem for the country. Under conditions as they exist today, the new high technology growth companies are not being organized in sufficient numbers to provide the jobs and the technical products for export which will be needed in the decades ahead. If the future economic health of the country is to be insured, it is apparent that something must be done to improve the business environment. It is probably impossible to quantitatively predict the extent to which any specific legislative of administrative change might stimulate or expedite the generation of new business enterprises. The following recommendations are suggested for Executive and Legislative action in order to enhance the initiation and growth of new technically based enterprises:

1. Change Capital Gains Tax. A reduced capital gains tax rate for direct investment in small technical enterprises should be an effective incentive to make venture capital available for "Start-ups". Such an incentive should be available to both corporate and individual investors.

2. "Founders'" Stock. A new mechanism is needed to facilitate the acquisition of "Founders'" stock by officers, directors, and key employees during the formative years of the company. Care should be taken to prevent adverse tax consequences which negate the value of the stock in attracting key talent to the enterprise team.

3. Recognize the Role of Corporate Investors. The institutionalization of the venture capital community and the increasing use of the industrial corporate venture mechanism suggest that it would be desirable to allow corporate and partnership participation under both Sub-Chapter S and Section 1244 of the Internal Revenue Code.

4. Tax Incentive for Direct Investment in Small Technical Enterprises. An immediate deduction against income for individual, institutional and corporate investors for their direct investment in small technical enterprises would be an effective incentive for start-up financing. The investors would assume a zero tax base, and capital gains tax liability would be incurred only upon sale of the investment.

5. Review SEC Rules. SEC rules, not withstanding Rule 144, continue to restrict the small company investor's liquidity. New combinations of holding periods and rates of distribution (for both private and public companies) should be considered.

6. Review Reporting Procedures. Reporting requirements under the rapidly growing state and federal regulations rules should be reviewed with the intent of simplifying the requirements for small companies.

7. Review Tax and SEC Regulations. General cost increases and inflation have made dollar limits in certain rules too small. For 1244 stock, the maximum asset value should be increased to $1,000,000; the loss allowance should be increases to $50,000 on an individual basis, and $100,000 on a joint return basis. Similarly, the capitalization limit for a Reg. A registration should be increased to $1,000,000. The small business 22% tax rate should be applied to the first $100,000 of income rather than $25,000. The tax-loss carry-forward period should be extended from five years to ten years.

8. Review Incentives for Management. For the new small enterprise, the value of stock options as a management incentive can be restored by reducing the holding period for shares issued under a qualified.

plan and arranging to defer tax liability for shares issued under a non-qualified plan. Other forms of financial and tax incentives should be developed for the management and key employees of the higher risk new technical enterprise.

Appendix A

Sales & Employment Data
1945 - 1974 & 1969 - 1974

	Sales Data					Employment Data				
	Sales 1974	Sales 1969	Sales 1945	Annual Rate 1969-1974 %	Annual Rate 1945-1974 %	Employment 1974	Employment 1969	Employment 1945	Annual Rate 1969-1974 %	Annual Rate 1945-1974 %
	($000 omitted)									
Young High Tech. Companies										
Data General	83,196	1,034	--	140.5	--	3,452	170	--	82.3	--
National Semiconductor	213,550	22,904	--	54.3	--	17,610	1,710	--	59.4	--
Compugraphic	61,412	8,067	--	50.2	--	1,864	637	--	24.0	--
Digital Equipment	421,884	87,868	--	36.8	--	17,600	4,615	--	30.7	--
Marion Labs	77,303	25,861	--	24.5	--	1,440	465	--	25.4	--
Total	857,345	145,734	--	42.5	--	41,966	7,597	--	40.7	--
Innovative Companies	($000,000 omitted)									
Polaroid	757.3	522.2	16.75	7.7	14.0	13,019	10,506	1,058	4.4	9.0
3M	2,937	1,613	63.55	12.7	14.1	83,609	66,260	6,795	4.8	9.0
IBM	12,675	7,197	141.7	12.0	16.8	292,350	258,662	17,300	2.5	10.2
Xerox (Haloid Co.)	3,576	1,483	6.716	19.2	24.2	101,380	54,882	593	13.1	19.4
Texas Instruments ('53-'74)	1,572	831.8	27.33	13.6	21.2	65,524	58,974	2,300	2.1	17.3
Total	21,517	11,647	N.A.	13.2	16.9	555,882	449,284	N.A.	4.3	11.1
Mature Companies	($000,000 omitted)									
Bethlehem Steel	5,381	2,928	1,327	12.9	4.9	122,000	130,000	202,095	(1.3)	(1.7)
DuPont	6,977	3,655	631.6	13.8	8.6	136,836	118,079	63,939	3.0	2.6
General Electric	13,413	8,448	1,298	9.7	8.4	404,000	400,000	148,233	0.2	3.5
General Foods	2,987	1,894	307.1	9.5	8.2	47,000	42,000	13,000	2.3	4.5
International Paper	3,095	1,777	240.0	11.7	9.2	52,715	54,500	23,414	(0.7)	2.8
Proctor & Gamble	4,912	2,708	342.5	12.6	9.6	49,800	43,214	14,800	2.9	4.3
Total	36,795	21,410	4,146	11.4	7.8	812.351	786,793	465,481	0.6	1.9

Source: Moody's Industrial Manuals, Moody's Investor Services, Inc., New York, New York

JOF:cji
October 3, 1975

Appendix B

New Small Company Public Issues
($ In Millions)

	Small Companies		Small Technical Companies	
	Dollars	Number	Dollars	Number
1969	$1,103	649	$349	204
1970	386	210	149	86
1971	528	244	138	73
1972	921	418	194	104
1973	158	67	38	19
1974	16	9	6	4
1975 (6 mos.)	4	1	0	0

Includes all "firm" underwritings of equity securities of less than $5 million for companies with net worth, prior to offering of less than $5 million. Excludes Regulation A offerings, "best efforts" sales, government securities and foreign issues. Data from Venture Capital published by S.M. Rubel and Company, Chicago, Illinois.

SOUTHERN SCIENCE APPLICATIONS, INC.

DIVISION OF BLACK & VEATCH

May 19, 1978

Honorable Adlai E. Stevenson
Chairman – Science, Technology
and Space Subcommittee
United States Senate
Washington, D.C.

Dear Senator Stevenson:

On behalf of the American Consulting Engineers Council, I would like to submit comments in connection with your subcommittee hearings on ways in which U.S. Government policy can contribute to U.S. technological superiority and create new trade opportunities for high technology exports.

For the past two or three decades, the improvements in technology have been enormous. For most of this period, the United States has enjoyed a position of world superiority in developing basic principles, skills, and understanding, and also in adapting and commercializing technological innovations for practical applications in this country and abroad. In recent years, however, U.S. superiority in the high-technology areas has been seriously eroded, not only by the developing indigenous capabilities and competitive positions of the more progressive foreign nations, but also by the almost-repressive taxation policies of the U.S. Government. Specifically, the 1976 revision to Section 911 of the Tax Code and the subsequent interpretations as applied to U.S. citizens employed in overseas assignments have placed U.S. industries in a difficult competitive position internationally. Other factors, such as escalation and its consequent impact on both the amount and effectiveness of public and private expenditures on research and development, also contribute to the deteriorating international position of high-technology industries in the U.S.

In my own field – nuclear power – other governmental restrictions (most derived from the valid desire to minimize the potential proliferation of nuclear weapons) also limit the marketing of consulting services internationally. However, as nonproliferation concerns are better understood, and as international cooperative agreements are consummated, it seems reasonable to anticipate that more foreign markets for nuclear consulting services will become available. We expect to seek international opportunities and would certainly hope to be able to compete with foreign firms — without being handicapped by tax penalties imposed by U.S. Government policies.

It appears to me that the current provisions of Section 911 of the Tax Code and the associated interpretations, penalizing U.S. nationals in overseas assignments and imposing cost premiums on U.S. corporations seeking international commerce, is short-sighted, seeking to reap an immediate tax windfall rather than deferring to a much larger potential tax income that would become available in the future. Therefore, I join others in petitioning for legislative relief

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from the unfair and trade-repressive provisions of the 1976 revisions to Section 911 and the "grossing up" interpretations related to cost of living, education, relocation, home-leave travel, etc. I believe this will be an important step toward restoring U.S. technological superiority and equalizing U.S. industry competitiveness in the international market for high-technology exports.

I respectfully request that this letter be entered in the hearing record.

Sincerely,

Kenneth E. Roach

Kenneth E. Roach
President

KER:jcg

cc: Bruce C. Roberts, Director
International Division
American Consulting Engineers Council

DEPARTMENT OF THE TREASURY
WASHINGTON, D.C. 20220

DEPUTY ASSISTANT SECRETARY

JUN 29 1978

Dear Mr. Chairman:

I appreciate the opportunity you gave me to testify before the Subcommittee on International Finance and the Subcommittee on Science, Technology and Space on May 16. I indicated during the question period that the Treasury Department would provide answers to several questions raised by you and Senators Proxmire and Schmitt.

1) Disaggregated figures

The attached table breaks down, on a product line basis, data for R&D intensity and trade performance in the manufacturing sector, and on an industry-wide basis, data for productivity. Industries are ranked by R&D intensity, and separated into above-average (high technology) and below-average (low technology) R&D intensity. Notice that high technology goods in general have a much more positive trade performance than low technology goods. In addition, average productivity per man is 50 percent higher for high technology goods than in the low-technology category. R&D figures relate to R&D performed in industry, yet financed both by private firms and by the U.S. Government.

2) Exploratory versus defensive R&D

We have attempted to determine if data exist which would indicate a shift in R&D away from efforts leading to product innovation and toward efforts designed to meet government regulatory requirements. We have been unsuccessful in obtaining such figures. A qualitative statement of this phenomenon appears on page 48 of an article from the July 3, 1978 issue of Business Week, attached. The same article reports a 10 percent rise in real R&D spending performed by industry between 1976 and 1977 (for various reasons, the MCGraw-Hill data are not entirely comparable with National Science Foundation data).

The National Science Foundation does collect data on industrial R&D spending for pollution abatement. In 1975, over half of all such expenditures were undertaken in the motor vehicles industry ($347 million). Within the motor vehicles industry, R&D spending on pollution abatement amounted to 17 percent of all R&D spending. Economists at the McGraw-Hill Publications Company have also kept track of R&D expenditures for pollution control. They claim that every major industry (with the exception of chemicals and nonferrous metals) is currently planning to increase its R&D work against pollution by 1980. Unfortunately, data on R&D for pollution abatement has not been collected for a sufficient time period to detect actual trends.

McGraw-Hill Publications also has collected data in three categories of R&D effort: new products, new processes, and improvement of existing products. For 1977, manufacturing enterprises put 28 percent of R&D effort in new products, 13 percent into new processes, and 59 percent into improving existing products. The categories, it should be cautioned, involve a fair degree of subjective distinction. R&D effort in any of the three categories has the potential for increasing efficiency and promoting economic growth.

As Senator Schmitt pointed out in his statement, basic research in industry (in constant 1972 dollars) has declined from a peak in 1967 of $796 million to $552 million in 1975. Half of this real dollar decline, however, can be attributed to a fall-off in basic industrial research in the fields of physics and astronomy, paralleling the decline of the space program.

If any clarification or further information is needed, I will try to be of help.

Sincerely yours,

Gary Hufbauer

Gary C. Hufbauer

The Honorable
Adlai E. Stevenson, Chairman
Subcommittee on Science,
Technology and Space
United States Senate
Washington, D.C. 20510

Attachments

	SIC-3 digit [1]	Description	R&D Intensity [2] (%)	Trade Balance Exports-Imports, 1976 ($ mil)		Productivity: Value added per man-hour (prod workers), 1975 (dollars)	
Above average R&D intensity	366-7	Communications equip.	15.20	793.7		19.21	
	372	Aircraft & parts	12.41	6,748.3		24.63	
	357	Office, computing equip.	11.61	1,811.4		30.19	
	383-7	Optical, medical instr.	9.44	369.6		26.78	
	283	Drugs & medicines	6.94	743.5		55.48	
	282	Plastic materials	5.62	1,448.0		27.05	
	351	Engines & turbines	4.76	1,629.2		20.66	
	287	*Agric. Chemicals*	4.63	539.3		65.26	
	19 (less 1925)	Ordnance (except missiles)	3.64	553.0		n.a.	
	381-2	Professional & scientific instr.	3.17	874.8		19.62	
	362	Elec. indus. apparatus	3.00	782.5		16.83	
	281	Indus. chemicals	2.78	2,049.4		38.60	
	365	Radio & TV receiving equip.	2.57	-2,443.4	1,223.0 av.	16.12	30.03 av.
Below average R&D intensity	352	Farm machinery	2.34	696.2		19.72	
	361	Electric *transmission* equip.	2.30	798.1		17.91	
	371	Motor vehicles	2.15	-4,588.6		19.27	
	363-4, 369	Other electrical equip.	1.95	311.2		16.78	
	353	*Construction*, Mining	1.90	6,160.4		21.60	
	284-6, 289	Other chemicals	1.76	1,238.5		48.42	
	34	Fabricated metal, prod.	1.48	1,525.7		16.30	
	30	Rubber & plastics	1.20	- 478.8		15.57	
	354	Metalworking mach.	1.17	736.4		16.12	
	373-5, 379	Other transport	1.14	72.1		13.09	
	29	Petroleum & Coal prods	1.11	n.a.		n.a.	
	355-6, 358-9	Other non-elec. mach.	1.06	3,991.3		17.38	
	21, 23-27, 31, 39	Other manufactures	1.02	-5,137.4		13.32	
	32	Stone, clay & glass	0.90	- 61.3		16.97	
	333-6, 3392	*Non-ferrous metals*	0.52	-2,408.9		19.70	
	331-2, 3391, 3399	Ferrous *metals*	0.42	-2,740.4		18.29	
	22	Textile Mill Products	0.28	40.3		8.73	
	20	Food & kindred prods.	0.21	- 190.0	2.0 av.	23.24	20.2 av.

1/ Measures of R&D intensity and trade balance are on a product line basis, whereas productivity data are on an industry basis.

2/ The *ratio* of applied R&D funds by product field to shipments by product class, averaged between 1968-70

Sources: Commerce Dept. BIEPR Staff *Economic Report*; Bureau *of* Census

VANISHING INNOVATION

A hostile climate for new ideas and products is threatening the technological superiority of the U. S.

A grim mood prevails today among industrial research managers. America's vaunted technological superiority of the 1950s and 1960s is vanishing, they fear, the victim of wrongheaded federal policy, neglect, uncertain business conditions, and shortsighted corporate management. They complain that their labs are no longer as committed to new ideas as they once were and that the pressures on their resources have driven them into a defensive research shell, where true innovation is sacrificed to the certainty of near-term returns. Some researchers are bitter about their own companies' lax attitudes toward innovation, but as a group they tend to blame Washington for most of their troubles. "[Government officials] keep asking us, 'Where are the golden eggs?' " explains Sam W. Tinsley, director of corporate technology at Union Carbide Corp., "while the other part of their apparatus is beating hell out of the goose that lays them."

That message—and its implications for the overall health of the U. S. economy—is starting to get through. Following months of informal but intense lobbying led by such executives as N. Bruce Hannay, vice-president for research and patents at Bell Telephone Laboratories Inc., and Arthur M. Bueche, vice-president for research and development at General Electric Co., the White House has ordered up a massive, 28-agency review of the role government plays in helping or hindering the health of industrial innovation. "Federal policy affecting industrial R&D and innovation must be carefully reconsidered," wrote Stuart E. Eizenstat, the White House's domestic policy adviser, in a recent memo outlining the review's intent.

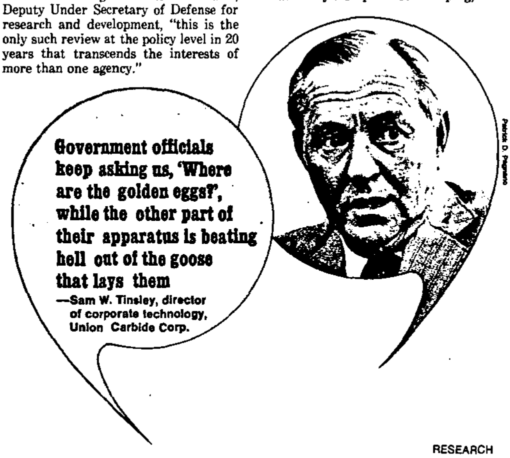
One thing that the study clearly will not accomplish is a quick fix for the deepening innovation crisis. The problem is regarded as immensely complex by the Administration, and is inextricably tied to other economic dilemmas now facing Carter's White House.

"Historically, the government's role has been to buy more science and R&D," says Martin J. Cooper, director of the strategic planning division at the National Science Foundation (NSF). "Now maybe we better go with investment incentives." Says Jordan J. Baruch, Assistant Commerce Secretary for science and technology, who will be the review's day-to-day manager: "This study developed in an environment of people concerned about economics, business, and technology."

The Administration's concern is underscored by the fact that it is organized as a domestic policy review, the highest sort of attention a problem can receive within the executive branch. Among its objectives, such a review must produce options for corrective action by the President. According to Ruth M. Davis, Deputy Under Secretary of Defense for research and development, "this is the only such review at the policy level in 20 years that transcends the interests of more than one agency."

The White House also seems determined not to conduct the study in a governmental vacuum. Baruch is soliciting input from groups such as the Industrial Research Institute (IRI), the Business Roundtable, and the Conference Board. "We want both CEOs and R&D vice-presidents," says a White House official. Labor groups have been asked to participate, too, along with public-interest groups. Congressional leaders such as Senator Adlai E. Stevenson (D-Ill.), chairman of the Senate subcommittee on science, technology, and space, have been brought into the early planning. And the 28 agencies involved extend beyond obvious candidates, such as the Environmental Protection Agency, to the Justice Dept. and even the Small Business Administration.

The study's scope is so sweeping, in



fact, that some federal officials are talking about a "thundering herd" approach to policymaking. But one government science manager demurs. "It beats having one guy write a national energy program in three months," he sniffs.

Philip M. Smith, an assistant to Presidential science adviser Frank Press and an early organizer of the study, concedes that "a lot of people have told us that we are likely to fail." But such skepticism, he believes, does not take into account the considerable clout of those involved in the effort. Commerce Secretary Juanita M. Kreps, for example, is chairing the study, and she heads a coordinating committee whose members include Charles L. Schultze, chairman of the Council of Economic Advisers, Administration inflation fighter and chief trade negotiator Robert S. Strauss, and Zbigniew Brzezinski, Carter's national security adviser. Even more important is the support of Eizenstat, who, says Smith, "is very interested in this particular review."

Finding 'new directions'

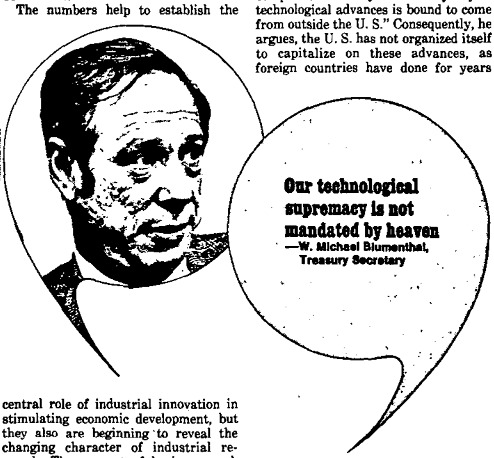
On the other hand, there is already grumbling within the Agriculture Dept., which was left off Kreps's committee. "We are red-faced," says a high-ranking Agriculture official. "We are out of the project because this Administration and those before it do not place any priority on agricultural research." However, Jordan Baruch insists that the department will play a role in the study. Agriculture experts point out that farm commodity exports of over $24 billion play a key role in the U. S. balance of payments. They note also that superior technology is the basis of the commanding American position among world food exporters.

Whatever its outcome, the White House policy review is being undertaken at a time when, as Frank Press puts it, "we badly need some new directions." Many experts view with alarm the declining federal dollar commitment to R&D, which has dropped from 3% of gross national product in 1963 to just 2.2% this year. For its part, industry as a whole has more or less matched the inflation rate and then some with its own spending. But such macroscale indicators do not tell all. "We've got to find out what the story is sector by sector, because each industry is going to be different," says Press. "We also have to find out what's going on abroad."

Better data on the relationship between industrial innovation and the health of the economy are becoming available. According to a 1977 Commerce Dept. report, for instance, technological innovation was responsible for 45% of the nation's economic growth from 1929 to 1969. The study went on to compare the performance of technology-intensive manufacturers with that of other industries from 1957 to 1973, and found that the high-technology companies created jobs 88% faster than other businesses, while their productivity grew 38% faster.

The numbers help to establish the central role of industrial innovation in stimulating economic development, but they also are beginning to reveal the changing character of industrial research. The amount of basic research that industry performs, for instance, has dropped to just 16% two years ago from 38% of the national total in 1956.

And a new IRI survey of member companies for the National Science Foundation demonstrates how federal policy has directly altered the nature of the research effort in another way, making it more and more defensive. The study shows that surveyed companies increased R&D spending devoted to proposed legislation by a striking 19.3%, compounded annually, from 1974 to 1977. And the rate was 16% a year for R&D devoted to Occupational Safety & Health Administration (OSHA) requirements. "When overall R&D spending is not growing nearly this fast," note the survey's authors, George E. Manners Jr. and Howard K. Nason, "other categories of effort—especially research—must be suffering."



Other observers compare the viability of industrial innovation in the U. S. with that of foreign countries. One expert is J. Herbert Hollomon, director of the Center for Policy Alternatives at Massachusetts Institute of Technology. According to Hollomon, a reason the U. S. is losing its leadership is that "we're arrogant—we have an NIH [not invented here] complex at the very time a majority of technological advances is bound to come from outside the U. S." Consequently, he argues, the U. S. has not organized itself to capitalize on these advances, as foreign countries have done for years with American knowhow. Since as much as two-thirds of all R&D is now conducted by foreign laboratories, Hollomon says, it should be no surprise that they have taken the lead in such technologies as textile machinery and steel production.

"We essentially prohibited West Germany and Japan from defense and space research," says Hollomon. "So it's no accident they concentrated on commercial fields." He adds: "I believe other nations better understand that the innovation process is important."

Says a research director for one high-technology company: "For a country like ours, the technology leader of the world, what has been happening is downright embarrassing." Indeed, even the presumed sources of strength in a consumer-oriented society are today under intense pressure. "Our experience with Japan in the consumer electronics industry—namely televisions, radios, audio, and transceiver equipment—shows some of our weaknesses," testified Gary G. Hufbauer, a Deputy Assistant Treasury Secretary, before a congressional subcommittee. In 1977, he said, "we had a $3.6 billion trade deficit with Japan in high-technology goods, and about two-thirds of this was accounted for by imports of consumer electronic goods."

The role of regulation

The cumulative response to these developments has been alarm. "The system has now sharpened its pencils in a way that discourages changes that are major," worries Robert A. Frosch, head of the National Aeronautics & Space Administration. "We have been so busy with other things that we may have inadvertently told the people who think up ideas to go away."

Even labor unions, which historically have left R&D decision-making up to corporate board rooms, now are complaining about lack of innovation. "Having helped to develop and pay for this technology," says Benjamin A. Sharman, international affairs director of the International Association of Machinists, "American workers have a right to demand government responsibility for using it to create new products, more jobs, better working conditions, and general prosperity." And Charles C. Kimble, research director of the Electrical, Radio & Machine Workers union, goes so far as to suggest that labor should now have a say in how industrial research money is spent.

Among research managers themselves, excessive or contradictory federal regulatory policy is the single greatest complaint. Hannay of Bell Labs points to Food & Drug Administration requirements as a case in point. According to one study, says Hannay, a 1938 application for adrenaline in oil was presented to the FDA in 27 pages. In 1958, a treatment for pinworms took 439 pages to describe. "By 1972," he says, "a skeletal muscle relaxant involved 456 volumes, each 2 in. thick—76 ft. in total thickness and weighing one ton."

Regulation, says Tinsley of Union Carbide, has put a bottleneck on new-product development in the chemical industry and has so added to the cost of getting any new chemical approved that only those targeted at a vast, assured market are attempted today. Food and drug industry researchers echo that complaint. "Today," says Al S. Clausi, director of technical research at General Foods Corp., "our industry does work that is fostered by unreal and invalid public concerns."

But regulation can have less obvious impacts, such as forcing an industry to stick with old technology rather than to experiment with new approaches to problems. "The overall effect of regulations on the auto industry has been to build an envelope around the internal-combustion device and the whole car structure," says Harvard Business School Professor William J. Abernathy, who specializes in technology management. " 'Don't do anything really new, don't change.' That's what these regulations say." Paul F. Chenea, vice-president for research at General Motors Corp., agrees. "You just don't have time to explore wild new ideas when a new rule is so closely coupled to your current business," he says.

'The science of the matter'

In Congress, where the regulatory laws are written, such thinking has so far found a small audience. "A great number of the regulations that we would call environmental . . . may actually be self-defeating," muses Harrison H. Schmitt, the former astronaut from New Mexico who is the ranking Republican on Stevenson's Senate subcommittee. "Instead of looking at pollution controls, if we were looking at building a more efficient and therefore less-polluting engine, we would not only be solving our environmental problems, but we would be producing a new thing for export."

Schmitt is one of only three federal legislators with the semblance of a science background. "We probably have

How antitrust charges can limit R&D payoffs

Companies that make it across the development minefield and bring superior technology to market still may find a threat on the other side: monopolization charges that keep them from fully exploiting the technology. As old as that problem is, such charges can come as a shock, as they did to Du Pont Co. last April.

Courts established decades ago that the Sherman act prevents a company with a hammerlock on a particular industry from making sound, otherwise perfectly legal business decisions that would, however, perpetuate its dominance. In 1945, for example, Judge Learned Hand found evidence that Aluminum Co. of America unlawfully monopolized its industry by its tendency to "double and redouble capacity" as demand increased. That, said Hand, locked would-be competitors out of the expanding market.

In a similar vein, the Federal Trade Commission said three months ago that Du Pont had used "unfair means" to keep competitors from increasing their share of the expanding market for titanium dioxide, a widely used paint pigment. "The complaint is wholly without basis," says Irving S. Shapiro, the company's chairman.

Du Pont's Shapiro: The FTC's "complaint is wholly without basis."

40% share. Superior technology clearly contributes to Du Pont's dominance. In the 1950s, the company devoted a decade of work—and what a spokesman will peg only at "many millions of dollars"—to develop a new way of making TiO_2. Although the highly automated, continuous process went on stream more than 20 years ago, it still tops the processes used by such competitors as NL Industries, SCM, and American Cyanamid, because it uses cheaper raw materials and produces less acid waste.

The problem with the government arises because Du Pont's 40% share of the $700 million-a-year market is still growing. That alone is enough to send government lawyers poking about for actions that can be attacked. According to Alfred F. Dougherty Jr., head of the commission's antitrust arm, even a 30% chunk of the market "could be a dominant position if all the other firms in the market had a much lower share." In fact, Justice Dept. antitrust chief John H. Shenefield asked his staff to look at Du Pont's TiO_2 policies only to find the FTC there ahead of him.

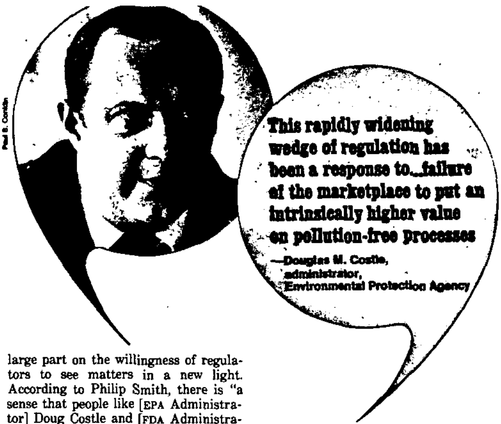
Basically, the FTC says that Du Pont keeps its market share by expanding capacity before the market is ready for more production, thereby forestalling competitors' expansion plans. Du Pont, says the FTC, should get rid of one of two current TiO_2 facilities and a new plant at De Lisle, Miss., that would begin production next year. The FTC staff also wants the company to take competitors under its wing by giving them, royalty-free, the superior technology and knowhow it has built up over the past 25 years.

exercised very poor judgment in the past," he says, "because the Congress overall—members as well as staff—have not been able to understand what is possible technologically and what is not, and therefore not been able to relate the costs [of legislation]."

Jason M. Salsbury, director of the chemical research division at American Cyanamid Co., pleads, "Before the lawyers write the legislation, let them know the science of the matter." Not only may some mandates be beyond what industry can legitimately perform, he says, but the rules force a conservative approach to science. One key indicator of this trend is the increasing number of toxicologists now employed in chemical company research labs. "Toxicologists don't innovate," notes Frank H. Healey, vice-president for research and engineering at Lever Bros. Co.

Then there is the regulatory bias against new ideas. In the EPA's grant programs for waste-water treatment at the municipal level, for instance, equipment specifications must be written so that gear can be procured from more than one source. That means a company with a unique process is discriminated against. What is more, the mandate for cost effectiveness precludes trying out innovative approaches whose value can only be measured if someone is willing to gamble on them.

If the domestic policy review is to solve such questions, it will depend in large part on the willingness of regulators to see matters in a new light. According to Philip Smith, there is "a sense that people like [EPA Administrator] Doug Costle and [FDA Administrator] Don Kennedy want to work with industry, and they don't want to fight all the time. I think we have a team of people now in government that may be able to do something."



The investment climate

But industry should not expect a major overhaul of regulatory practices to emerge from the study. EPA Administrator Douglas M. Costle concedes "a tremendous growth in the last decade in health and safety regulations—13 major statutes in our area alone." Though Costle agrees that the economic impact of such rules should be more closely quantified, he contends that "this rapidly widening wedge of regulation has been a response to a massive market failure—failure of the marketplace to put an intrinsically higher value on pollution-free processes."

Most regulators agree that not enough research has been done on the true nature of the environmental problems they are empowered to combat, but they also argue that regulation has led to cost-saving practices, especially in the area of resource recovery, where closed-cycle processes now help capture reusable material. OSHA officials also cite examples where the agency has laid down rules that have led to cost-cutting innovations. But Eula Bingham, the OSHA administrator, emphasizes that the "legislatively determined directive of protecting all exposed employees against material impairment of health or bodily function" requires tough regulation without quantitative weighing of costs and benefits. "Worker safety and health," she insists, "are to be heavily favored over the economic burdens of compliance."

Bingham and her boss, Labor Secretary Ray Marshall, may represent an increasingly isolated view, however. Economic issues have come to dominate thinking within the Carter Administration, and it is precisely these questions that industry has stressed in its discussions with science adviser Press and other White House officials. Just over a month ago, Treasury Secretary W. Michael Blumenthal told a meeting of financial analysts in Bal Harbour, Fla., "We are now devoting a very sizable chunk of our private investment to meeting government regulatory standards . . . and in some of these areas we may well be reaching a breaking point." Blumenthal also noted: "Our technological supremacy is not mandated by heaven. Unless we pay close attention to it and invest in it, it *will* disappear."

A month before the Blumenthal speech, GE's Bueche suggested to an American Chemical Society gathering that "we step back and look at R&D for what it really is: an investment. It is an investment that, like more conventional investments, has become increasingly less attractive."

Bueche, along with most other research managers, rejects the idea of direct federal subsidies to industrial R&D. Instead, he points out that "perhaps 90% of the total investment required for a successful innovation is downstream from R&D, [and thus] it becomes . . . clear why we must concentrate on the overall investment climate." Bueche attacks Administration proposals to eliminate special tax treatment of long-term capital gains, plumps for more

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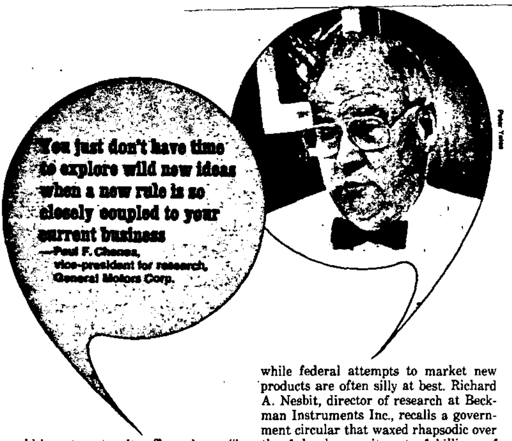
Whether the need for such onerous penalties can be established—before an FTC judge, the full commission, then a court of appeals and, perhaps, the Supreme Court—may take years to determine. But the approach is not unusual in monopolization cases.

The Xerox case. Just a year ago, the Justice Dept. ended such a suit against Industrial Electronic Engineers Inc., by getting the California company to promise royalty-free licenses to all comers on patents it had used to dominate the market for rear-projection readout equipment for electronic data-processing systems. And three years ago, the FTC settled a complaint by getting Xerox Corp. to open its portfolio of 1,700 copier patents to competitors. Xerox had to license three patents—chosen by the competitors—free. Fees for use of the rest were strictly limited by the FTC.

As severe as those measures may seem, and as discouraging to innovation, the antitrusters contend that it is the only way rivals can eat into a monopolist's dominance of a market. Says Alan K. Palmer, assistant director of the FTC's antitrust arm: "We have to look to what relief will really be effective."



rapid investment write-offs, and says "it is extremely important to provide stronger incentives for technological innovation by making permanent and more liberal the 10% investment tax credit."

Critics in industry

Bueche's arguments suggest the broad—yet often indirect—way in which federal policy runs counter to the best interests of innovation. Fear of antitrust moves from the Federal Trade Commission or the Justice Dept., for instance, has prevented many companies from sharing research aimed at a problem common throughout an industry—including new technology aimed at solving regulatory questions. At General Electric, the legal staff must now be notified if a competitor visits a company research facility, even if no proprietary material is involved.

For their part, Justice Dept. trustbusters claim that fears that their policies stifle innovation are not justified. They say they are flexible enough to recognize the differences in the pace of innovation from industry to industry, and that is why they allow a fair number of mergers among electronics companies. "That's an industry where you don't have to worry about someone cornering the market," says Jon M. Joyce, an economist in the Justice Dept.'s antitrust division. "There's just a lot of guys out there with good ideas."

Industry further claims that the inability to secure exclusive licenses on government-sponsored research leaves much good technology on the shelves, while federal attempts to market new products are often silly at best. Richard A. Nesbit, director of research at Beckman Instruments Inc., recalls a government circular that waxed rhapsodic over the federal commitment of billions of dollars to R&D. Included with the letter was a syringe for sampling fecal matter, and the suggestion that Beckman might want to license the technology. "I wondered if they spent billions to develop that," Nesbit recalls. "The contrast was ludicrous."

Even national accounting procedures draw criticism from industry. A major target is the 1974 ruling by the Financial Accounting Standards Board that stipulated that R&D spending could no longer be treated as a balance sheet item, but must be listed as a direct profit or loss item in the year spent. R. E. McDonald, president and chief operating officer at Sperry Rand Corp., recently told an executive management symposium, "The ramifications of that rule change are quite complex, but the net effect has been to dry up a lot of potential venture capital investments. . . . I can say quite candidly that Univac would not be here today if we had not had the advantage of the old rule for so many years."

The shortage of risk capital has had a tremendous impact on small, technology-oriented companies trying to arrange new public financing. According to a Commerce Dept. survey, 698 such companies found $1.367 billion in public financing in 1969. In 1975, only four such companies were able to raise money publicly, and their numbers rose to just 30 in 1977. Equally ominous is the experience at Union Carbide, which, according to Tinsley, has not been able to compete for venture capital and has thus canceled plans to start a number of small operations built around interesting new technology. Years ago, says Tinsley, Carbide was reasonably successful at getting such funding. "And you must remember that these ideas are perishable," he says. "They don't have much shelf life."

The Treasury Dept., in fact, has an ongoing capital-formation task force that will be integrated into the policy review under the direction of Deputy Secretary Robert Carswell. Carswell notes that "you can't draw a clear line" between R&D support and investment in general, but "if it turns out that we find some form of capital formation gives the economy a greater multiplier effect than another form, we at the Treasury would not shy away from whatever policy would help most."

Washington's changing role

Even as it has pursued policies detrimental to industrial R&D, the federal government has withdrawn as a major initiator of innovation. Research managers generally believe that companies are better equipped than government to bring new technology to society because they are more attuned to market pull. But Lawrence G. Franko of Georgetown University, an international trade expert, recently pointed out to a congressional committee that the U. S. government has in the past played an important role "as a source of demand for new products and processes, and as a constant, forbearing customer in computers, semiconductors, jet aircraft, nuclear-power generation, telecommunications, and even some pharmaceuticals and chemicals. . . ."

According to the Defense Dept.'s Davis, both Defense and NASA "have faded" in this role, the result of the Vietnam war and concerns over the military-industrial complex. "The consumer marketplace and other government agencies have not been able to pick up where DOD and NASA left off," she says. "The Department of Energy should be able to help with this, but it hasn't yet. And the Department of Transportation just never blossomed in this role." An unreleased IRI study for the Energy Dept. summed up industry's views. The company officers interviewed said government could spur industry's energy R&D only by creating a national energy policy, increasing its managerial competence, and offering financial incentives rather than massive contracts.

On the other hand, there have been some recent, notable government efforts to spur the innovation process. "We've talked to the leading semiconductor companies about our hopes for their innovation," says Davis. She says that the Defense Dept. expects to program $100 million over the next five years for industrial innovation in optical lithography, fabrication techniques involving electron-beam technology, better chip designing and testing to meet military specifications, and system architecture and software implementation.

At the Transportation Dept., chief scientist John J. Fearnsides wants to involve the private sector much earlier in the government's R&D process, thereby allowing industrial contractors to develop technology alternatives instead of having to cope with rigid specifications at the outset. Such a policy, some believe, might have resulted in major savings for the Bay Area Rapid Transit system, for instance. "It is more expensive to fund a wider range of choices, but only at first," says Fearnsides.

The NSF also has announced a new industry-university grant program for cooperative exploration of "fundamental scientific questions." The aim is to make "a long-term contribution toward product and/or process innovation."

R&D is an investment that, like more conventional investments, has become increasingly less attractive
—Arthur M. Bueche, vice-president for research and development, General Electric Co.

The failures of business

While agreeing on the need for federal policies that bolster innovation, those knowledgeable about industrial research think that the companies themselves share some of the blame for stagnation and must be willing to examine their practices critically. Alfred Rappaport, a professor of accounting and information systems at Northwestern University's graduate school of management, believes that one reason the U. S. lags in R&D is that the incentive compensation systems that corporate executives live under tend to deter intelligent risk-taking. "Incentive programs are almost invariably accounting-numbers oriented and based on short-term earnings results," he says. "That puts management emphasis on short-term business considerations."

Another criticism has been of the haphazard way in which companies have launched new R&D programs. In essence, industry should try to learn how to weed out bad ideas early on, say the detractors. To that end, Dexter Corp. has instituted an eight-factor "innovation index" approach to research management that weighs questions such as effectiveness of communications, competitive factors, and timing, and comes up with an "innovation potential" for new ideas. At Continental Group Inc., D. Bruce Merrifield, vice-president of technology, says that "constraint analysis" of new ideas now means that eight of 10 projects that survive the review will generate cash flow within two to four years. That contrasts with accepted estimates that only one in 50 ideas that come out of research labs ever generates cash flow, and not for seven to 10 years.

Large companies often fail to exploit their own resources effectively. In the 1950s and 1960s, some companies set up centralized research facilities, but many of these did not yield the hoped-for synergism—in many cases, apparently, because the different parts of the company were in businesses too unrelated to one another.

On the other hand, Raytheon Co. was highly successful in transferring its microwave expertise to its newly acquired Amana appliance subsidiary in 1967, resulting in the counter-top microwave oven. That was done through a new-products business group set up specifically for such purposes. And more recently, this group, headed by Vice-President Palmer Derby, brought the company's microwave talent to bear on its Caloric subsidiary's product line, resulting in a new, combination microwave-electric range.

In such ways, industry can maximize its potential for innovation in the most adverse environment. But the future health of the nation's economy, many experts believe, requires a much more benign environment for industrial R&D than has existed over the past decade. And Jordan Baruch, the enthusiastic leader of the multi-agency federal study, believes that such an environment is likely to emerge as a result of the Administration's concern.

"We may have bitten off more than we can chew," notes Frank Press, "and it may be that we can't get much done in a year. But even if it takes three or five or 10 years, I think it is historically very important." ■

Turning to Japan for venture capital

The recent drag in U. S. venture-capital commitments has opened opportunities for foreign companies to appropriate American ideas. A case in point is the experience of System Industries Inc., a Sunnyvale (Calif.) manufacturer of minicomputer peripherals.

In 1969, System Industries went to work on a new ink-jet printing process, forming a subsidiary, Silonics Inc., to develop and market it. By 1973, the research phase was over, and a cash-short System Industries went looking for venture capital to tool up for production. Unfortunately, none was there. With a depressed stock market, and recent increases in the maximum tax on capital gains that cut the expected return on such investments in half, the usual capital sources "couldn't justify taking the same risks they used to," says Edwin V. W. Zschau, the company's chairman and chief executive officer.

Keeping only 51%. Next, he explains, "we were thinking about government funding. But we were discouraged from even making a proposal when we learned the government would get data rights and be able to license it to other people. We didn't see why we should give away those rights just to get a little money." What Zschau finally did give up was 49% of Silonics to Konishiroku Photo Industry Co., the Tokyo-based maker of Konica cameras.

In return, the Japanese company has spent $5.5 million on Silonics, which is enough to bring the new printer to market at the National Computer Conference in Anaheim, Calif., in mid-June. "We have one of the most promising imaging technologies for the 1980s," Zschau now complains. "But we only own 51% of it."

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BUSINESS WEEK'S R&D SCOREBOARD: 1977

R&D SPENDING PATTERNS

The BUSINESS WEEK R&D Scoreboard for 1977 shows that companies surveyed spent a combined total of more than $18 billion on R&D last year, a substantial 16.4% jump over their 1976 expenditures. The numbers suggest that industry is now taking a more purposeful attitude toward new-product and process development, but there are important caveats to that conclusion.

N. Bruce Hannay, vice-president for research and patents at Bell Telephone Laboratories Inc., says the results add up "to just about what I expected." Noting that there is no way of telling how the funding is divided between low- and high-risk R&D, Hannay says, "the spending indicators are good, but they're not great."

Indeed, after the scoreboard numbers are adjusted for inflation, the increase over 1976 shrinks to just above 10%. Overall, R&D spending remained constant in relation to sales, at 1.9%, and edged up a bit as a percent of profit, to 34.6% last year from 33.9% in 1976. Profits themselves rose 9.6%, off from their 11.5% rise in 1976.

The 624 companies on the scoreboard account for about 90% of all the privately funded R&D performed by all U.S. companies. They include all companies that reported sales in excess of $25 million and R&D expenditures of at least $1 million or 1% of sales, whichever is less.

Since 1976, the first year of the BUSINESS WEEK survey, R&D costs reported on 10-K statements filed with the Securities & Exchange Commission presumably have met a strict definition of such expenses that has been adopted by the Financial Accounting Standards Board. It is thus possible to compare R&D intensity from company to company within an industry, as well as to compare R&D expenses among various industry groups themselves.

In brief, the FASB defines R&D expenses as those costs for all activities that lead to new technical knowledge as well as to the development of new products and processes. The standard specifically excludes a number of activities that often were reported as R&D costs in the past. The major exclusions are:

- Research performed under contract for others, such as the federal government. More than half of the total R&D performed by General Electric Co., for instance, is government-financed.
- All market research, often a large expense item for consumer product makers, such as Procter & Gamble Co.
- Follow-on engineering cost and "normal" product improvement and quality control, including product testing.
- Virtually all expenses associated with computer programming, whether the programming is by the manufacturer in support of its products, or by computer users. Thus, the rule will tend to understate the development costs of companies in data-processing services and equipment industries, where software is a significant portion of the new-product development effort.

All leading R&D surveys, including those of BUSINESS WEEK, Battelle Memorial Institute, and one produced by the National Science Foundation from Census Bureau data, approach R&D expenses differently. So, the surveys are not comparable, although they may often show the same trends.

How companies are grouped

For this year's BUSINESS WEEK Scoreboard, the criteria for inclusion of a company were changed only slightly from last year's. Formerly the cutoff was $35 million in annual sales, and the company must have spent at least $1 million on R&D regardless of that sum's relation to sales. The net effect of this year's changes is to add a dozen or so smaller companies to the list, particularly in the electronics category.

Three measures of the top 10 in R&D spending

In total dollars (millions)

1. General Motors	$1,451
2. Ford Motor	1,170
3. International Business Machines	1,142
4. American Telephone & Telegraph	718
5. General Electric	463
6. United Technologies	368
7. Du Pont	367
8. Eastman Kodak	351
9. Chrysler	337
10. International Telephone & Telegraph	280

In percent of sales

1. Systems Engineering Laboratories	12.1%
2. Data General	10.2
3. Fairchild Camera & Instrument	9.5
4. American Microsystems	9.4
5. AMP	9.2
6. Hewlett-Packard	9.2
7. Upjohn	9.0
8. Advanced Micro Devices	8.9
9. John Fluke	8.9
10. Amdahl	8.8

In dollars per employee

1. Amdahl	$8,679
2. International Flavors & Fragrances	5,891
3. Communications Satellite	5,468
4. Upjohn	5,431
5. Polaroid	5,426
6. Church & Dwight	5,392
7. Lubrizol	5,306
8. Eli Lilly	5,236
9. Merck	5,157
10. Systems Engineering Laboratories	4,917

FOR 600 COMPANIES

Changes were also made in industry groupings. Automotive companies were separated into two categories in recognition of the big differences between the major vehicle builders and their suppliers. Electronics companies were separated from older companies still heavily associated with electrical equipment and components. At the same time, semiconductor producers, with their heavy R&D commitment, were isolated from the rest of the electronics industry. Finally, the makers of computers and peripherals were separated from the makers of other office equipment.

As in previous years, some very large companies are notable by their absence. In most cases, absence of a company with annual sales in the hundreds of millions of dollars means that it did not report R&D expense in its most recent 10-K filing. Although the 10-K filings are not always explicit, the implication in such cases is that the company spent less than 1% of its sales on R&D. Many of the largest absentees, such as Mobil and Tenneco, would fall under the fuels category. Beatrice Foods and PepsiCo are multibillion-dollar giants missing from the food and beverage category. International Paper and Mead are missing from paper, Armco and Inland from steel, and Levi Strauss and Genesco from textiles and apparel.

BUSINESS WEEK provides the only comprehensive company-by-company breakdown of R&D spending. But the Census Bureau, using confidential surveys, can analyze how research dollars are divided among basic research, applied research, and development work. These confidential numbers are then combined on an industry basis and published annually by the NSF. The Census researchers caution that the numbers thus reported are not directly comparable with those combed from 10-K statements because of differences in procedure and definition.

BUSINESS WEEK, for instance, includes R&D spending by foreign subsidiaries and operations, while the Census Bureau covers only domestic expenditures. Census also includes engineering follow-on expenses in its totals. As a result of these differences, a recent Census Bureau internal study found that variations between data provided on 10-K reports and their survey can run to as much as 25% for a third of the companies covered.

Using the numbers

Now that the BUSINESS WEEK survey is in its third year, a number of individuals and companies are making innovative use of the numbers. Martin J. Cooper of the NSF and Herbert S. Bennett of the National Bureau of Standards, for instance, have established to their satisfaction a connection between job formation and R&D spending on the basis of the BUSINESS WEEK survey. At the Food & Drug Administration, researchers are dissecting the survey's results to see how proposed drug reform legislation might affect the health of the drug industry.

The spending indicators are good, but they're not great

—N. Bruce Hannay, vice-president for research and patents, Bell Telephone Laboratories Inc.

In Minneapolis, stockbroker Ron J. Burger of Dean Witter Reynolds Inc. has used the survey to develop a price/R&D ratio (BW—May 29). As he explains it, a company with 10 million shares outstanding may spend $125 million on R&D, or $12.50 per share. If the stock is selling at $50 a share, its price/R&D ratio is 4.0, meaning that the investor gets 25¢ worth of R&D each year for every dollar he invests. According to Burger, any company spending above 10¢ per investor dollar is worth considering. "More and more investors are starting to take note of the R&D figure," he says.

At General Electric, company researchers are now using the survey numbers to gauge their own R&D intensity—and relative effectiveness—against that of competitors in various industries. Over time, GE hopes to construct a hypothetical company against which it can measure itself, and thus find early warnings of weakness or unsuspected strengths in the marketplace.

This year's survey once again reveals the wide diversity of R&D commitment among various industry groups, and within industries themselves. Companies listed in the fuels category spent a composite 8.2% of profits on R&D, the lowest of any group. The semiconductor group topped all industries in committing a sum equivalent to 117% of profits to R&D. The automotive group of seven

...facturers spent more than ...n R&D in 1977 to lead all ... textile and apparel manu... ...ined for only $29.2 mil... ...res ...n c... ...iso... mislead... Ab... of ...tomotive ...gure is ...," ... ...ut Paul F. Che... ...nt ... research at G... ...rs Corp. "Fifteen percent ... ...pment, and 10% is applied. ...try does almost no basic ... And the textile group, like ...categories in the survey, draws heavily on the research done in other industries. Says Frank X. Werber, vice-president for R&D at J. P. Stevens & Co.: "You could add hundreds of millions of dollars when you think of the draw we make on the R&D output of fiber and chemical manufacturers."

Instrument makers, another industry that draws on research in other areas, such as semiconductor manufacture, showed perhaps the widest swings in relative R&D commitment within an industry classification. Thus, Technicare Corp. increased spending by 108% in 1977, while Bulova Watch Co. was off 7%. The differences can be explained by the varying character of the instruments produced by the many companies in the group, but Richard A. Nesbit, director of research at Beckman Instruments Inc., notes that the companies vary in relative maturity as well as the uneven pace with which certain technologies are advancing within the classification as a whole.

Trend indicators

In containers, another group where such wide variations are obvious, a research director cautions against reading too much into a downswing or rise. "If a company is getting out of one business and getting into another, the R&D budget can be affected enormously," he says. In fact, a mature product, supported by R&D for years, may be thought fully developed by management, and its R&D support slashed. At the same time, innovative new projects may be coming on line, but need not be supported in the heavy way a product further down the development line must be. Hence the importance of the numbers as trend indicators, rather than as spot measures of relative R&D health.

Food and beverage companies, for instance, registered R&D spending gains of 17.3% in 1976 and 15% this year, somewhat ahead of the all-industry composite. According to Al S. Clausi, vice-president and director of technical research at General Foods Corp., the rise results from the "clear impact" of such issues as ingredient testing on the cost of R&D. He also notes that "convenience alone is not enough" for consumers, who now demand more naturalness in food, as well as nutrition.

Glumly, Clausi reports that new products in his industry tend to be variations on existing products, such as new flavors or packing sizes. He points in contrast to the 1960s, when really new food technology produced instant soups and breakfasts, as well as toaster products.

Still another hidden factor in examining the R&D figures is the extent to which personnel costs are affecting budgets. Personnel, agree many research managers, are the greatest single source of increased costs of doing R&D, and personnel expenses are now outstripping inflation. "My budget is going up a little," reports W. Gale Cutler, director of corporate research at Whirlpool Corp. "But it is absolutely flat in terms of people." Like a number of his counterparts in industry, Cutler says also that "we are and have been diverting people from new products and processes" to do "defensive" research.

The appliance industry, he adds, "is hustling to get microprocessors into every product it can." In fact, the increasing technological competitiveness in his business has helped to keep research healthy, says Cutler. Yet he lists a number of factors that he must deal with that are beyond his control. Among them is the energy situation, which has put a premium on organic coatings technology to supplant the porcelain-enamel finishes that require high temperatures for curing. The resource crunch has also affected appliance makers, Cutler says, making them search for substitutes, such as aluminum for copper or polymeric materials for steel.

Sensitivity to downturns

But the heaviest pressure on his research operation may have already passed. "I think R&D in this industry is healthier now," says Cutler. "It's shaken out. You don't see budgets going up, but we're working much smarter than we were five years ago."

Still, industrial researchers warn that this year's increase in R&D spending, a brisker advance than in the first two years of the BUSINESS WEEK survey, should not be taken as a sign that things have turned around for them. A business downturn, they say, will likely send their budgets plummeting. The chemical industry, where profit increases fell from a 17.3% rate in 1976 to 6.8% this year, "could be another steel industry in 10 years," warns one manager. The example is a dire one indeed. In 1976 the ailing steel industry increased profits and R&D expenditures by 20%. Last year the steelmen's profits fell by 15.6%, and they increased their R&D budgets by just 0.1%, a net loss to inflation. ■

GLOSSARY

Sales 1977: Includes all sales and other operating revenues.

Sales percent change from 1976: Change in sales from 1976, restated, to 1977.

Sales percent average annual change: Annual change in sales, as restated, over the last five years.

Profits 1977: Net income before extraordinary items or discontinued operations.

Profits percent average annual change: Annual change in net income before extraordinary items or discontinued operations, as restated, over the last five years.

R&D expenses 1977: Dollars spent on company-sponsored research and development for the year, as reported to the Securities & Exchange Commission on Form 10-K. Excludes any expenditures for R&D performed under contract to others, such as U.S. government agencies.

R&D percent change from 1976: Change in R&D expenses from 1976, restated, to 1977.

R&D percent of sales: R&D expenditures as percent of sales and other operating revenues.

R&D percent of profits: R&D expenditures as percent of net income before extraordinary items and discontinued operations.

R&D dollars per employee: R&D expenditures divided by the reported number of company employees.

Employment percent average annual change: Annual change in number of employees, using restated figures, over five years.

All rates of change are calculated using a log linear least squares method. A rate is indicated NA if the rate for the first or last year is negative or if the rates for two or more years in the series are negative.

Data are for calendar 1977 except for those companies reporting on a fiscal year other than calendar basis, in which case the most recent annual data are used. Companies included in the survey are limited to those reporting 1977 sales of $25 million or more and R&D expenses amounting to at least $1 million or 1% of sales, whichever is less. With the exception of companies in telecommunications with significant manufacturing or research efforts, no regulated utilities or transportation companies are included in the survey.

Data: Standard & Poor's Compustat Services Inc. NA = Not available

R&D SPENDING: 1977

COMPANY	SALES: 1977 MILLIONS OF DOLLARS	SALES: PERCENT CHANGE FROM 1976	SALES: PERCENT AVERAGE ANNUAL CHANGE	PROFITS: 1977 MILLIONS OF DOLLARS	PROFITS: PERCENT AVERAGE ANNUAL CHANGE	RESEARCH & DEVELOPMENT EXPENSE: 1977 MILLIONS OF DOLLARS	R&D: PERCENT CHANGE FROM 1976	R&D: PERCENT OF SALES	R&D: PERCENT OF PROFITS	R&D: DOLLARS PER EMPLOYEE	EMPLOYMENT: PERCENT AVERAGE ANNUAL CHANGE
AEROSPACE											
Beech Aircraft	417	20.3	19.6	25	26.6	9.7	22.0	2.3	37.9	1064	8.3
Bertea	46	31.2	12.5	2	11.1	0.7	26.2	1.6	31.2	598	3.7
Boeing	4019	2.6	4.3	180	33.2	221.6	16.3	5.5	122.9	2904	1.5
Cessna Aircraft	620	25.8	12.8	37	15.0	31.4	37.1	5.1	85.0	1962	9.8
Fairchild Industries	399	51.5	11.5	10	19.9	2.9	164.0	0.7	30.4	305	7.7
Grumman	1553	3.4	10.8	32	15.7	17.7	-9.7	1.1	54.6	656	1.2
Lockheed	3373	5.3	3.9	55	38.6	56.6	4.6	1.7	102.2	1027	-5.1
McDonnell Douglas	3545	0.0	4.9	123	-1.4	123.9	17.3	3.5	100.8	2012	-7.6
Northrop	1601	26.6	22.8	66	51.8	31.5	22.2	2.0	47.6	1201	1.9
Rockwell International	5859	12.8	16.3	144	3.6	97.0	12.4	1.7	67.3	842	4.4
Rohr Industries	338	-6.8	4.7	3	-51.4	1.5	-43.9	0.4	49.1	189	-2.2
Thiokol Corp	447	22.4	11.5	21	12.1	8.7	28.7	2.0	40.6	992	3.1
United Technologies	5551	7.4	24.8	196	32.8	368.3	2.8	6.6	187.9	2658	20.1
Industry composite	27768	8.2	11.6	896	16.9	971.5	10.1	3.5	108.4	1758	3.5
APPLIANCES											
Hoover	591	3.3	3.3	23	-10.2	5.5	17.6	0.9	23.4	235	-3.3
Magic Chef	297	20.8	7.4	14	15.4	1.9	3.1	0.6	13.8	399	0.0
Reece	37	-1.5	2.4	3	-12.8	1.1	14.3	3.0	34.9	1012	-1.0
Ronson	119	5.5	-0.6	-9	NA	1.8	-5.4	1.5	-20.3	417	-9.1
Singer	2285	8.0	3.8	75	-4.7	23.5	18.9	1.0	31.5	273	NA
Sunbeam	1047	9.7	14.4	34	3.0	14.8	24.1	1.4	43.5	526	NA
Tappan	292	9.9	4.7	2	NA	3.0	15.4	1.0	151.3	577	-0.8
Whirlpool	1937	21.5	6.9	110	18.1	29.2	10.9	1.5	26.6	1240	-5.9
White Consolidated Industries	1400	12.2	13.4	54	11.6	11.7	17.0	0.8	21.7	394	6.0
Zenith Radio	966	1.9	0.8	8	-25.5	31.9	9.6	3.3	421.5	1334	-4.4
Industry composite	8968	10.9	6.5	313	- 2.3	124.4	12.1	1.4	39.6	541	1.6
AUTOMOTIVE: Cars, trucks											
American Motors	2237	-3.4	6.7	3	NA	43.3	11.5	1.9	1411.9	1467	3.0
Chrysler	16708	7.5	11.4	125	NA	337.0	20.4	2.0	270.0	1344	NA
Ford Motor	37842	31.2	12.7	1673	25.0	1170.0	26.5	3.1	69.9	2441	0.3
Fruehauf	1797	22.0	17.3	61	18.9	14.7	19.2	0.8	24.2	502	3.5
General Motors	54961	16.5	13.4	3338	19.5	1451.4	18.4	2.6	43.5	1821	-0.2
International Harvester	5975	8.9	9.2	201	18.4	114.6	17.0	1.9	56.9	1230	NA
White Motor	1254	15.3	3.8	1	-44.8	13.0	30.0	1.0	1144.2	1344	NA
Industry composite	120774	18.5	12.4	5402	20.7	3144.1	17.9	2.6	58.2	1862	0.1
AUTOMOTIVE: Parts, equipment											
American Safety Equipment	95	4.5	2.6	3	12.0	1.6	67.1	1.7	52.3	471	8.8
ASPRO	64	-1.2	6.5	3	11.9	0.7	23.5	1.1	28.4	485	1.5
Bendix	3283	11.4	10.2	118	14.9	45.6	19.1	1.4	38.6	566	0.5
Champion Spark Plug	569	10.8	8.1	50	0.0	6.3	12.5	1.1	12.7	450	1.4
Cummins Engine	1264	22.6	17.6	67	33.8	41.3	24.0	3.3	61.6	1877	4.5
Dana	1794	24.2	16.0	108	18.4	20.5	24.2	1.1	19.0	782	NA
Donaldson	141	16.6	14.3	9	14.2	4.1	18.2	2.9	44.8	1370	NA
Eaton	2111	16.7	6.7	106	4.5	31.0	9.0	1.5	29.2	665	-0.8
Federal Mogul	489	11.7	8.7	28	21.7	4.5	7.5	0.9	16.3	340	NA
Gleason Works	100	16.4	5.7	7	NA	3.5	9.4	3.5	47.1	1129	-4.2
Hayes-Albion	200	9.5	13.8	11	16.9	2.1	12.7	1.0	18.4	444	2.2
Irvin Industries	71	-16.7	10.6	-1	NA	1.2	-8.4	1.7	-180.0	506	3.6
Maremont	318	2.1	8.0	11	11.6	1.8	-8.6	0.6	16.6	241	1.8
Raybestos-Manhattan	251	9.1	9.8	9	12.9	4.4	25.0	1.8	48.2	782	-4.9
Sealed Power	207	14.1	15.3	11	17.6	2.6	15.6	1.3	23.0	526	5.1
Sheller-Globe	533	11.0	19.1	17	27.4	3.9	15.5	0.7	23.4	267	NA
A. O. Smith	727	17.4	10.7	17	12.3	12.8	25.5	1.8	77.3	948	-6.5
Standard Products	152	4.1	15.0	6	16.2	1.8	-7.8	1.2	29.1	436	0.7
Sun Electric	102	24.5	15.4	7	28.3	4.1	18.2	4.0	59.5	1287	6.7
TRW	3264	11.4	10.4	154	16.7	43.6	18.1	1.3	28.2	500	[illegible]
Timken	974	10.2	11.1	74	7.1	7.9	7.5	0.8	10.6	341	[illegible]
Industry composite	16710	13.9	11.0	816	13.3	245.4	15.9	1.5	30.1	838	[illegible]

R&D SPENDING: 1977

COMPANY	SALES: 1977 MILLIONS OF DOLLARS	SALES: PERCENT CHANGE FROM 1976	SALES: PERCENT AVERAGE ANNUAL CHANGE	PROFITS: 1977 MILLIONS OF DOLLARS	PROFITS: PERCENT AVERAGE ANNUAL CHANGE	RESEARCH & DEVELOPMENT EXPENSE: 1977 MILLIONS OF DOLLARS	RESEARCH & DEVELOPMENT EXPENSE: PERCENT CHANGE FROM 1976	RESEARCH & DEVELOPMENT EXPENSE: PERCENT OF SALES	RESEARCH & DEVELOPMENT EXPENSE: PERCENT OF PROFITS	RESEARCH & DEVELOPMENT EXPENSE: DOLLARS PER EMPLOYEE	EMPLOYMENT: PERCENT AVERAGE ANNUAL CHANGE
BUILDING MATERIALS											
Ameron	236	13.1	9.0	6	0.8	1.0	-16.9	0.4	15.5	241	2.0
Bird & Son	277	17.2	18.7	17	12.9	1.8	10.9	0.6	10.5	475	6.1
Boise Cascade	2316	19.9	15.1	116	4.4	4.0	20.4	0.2	3.4	106	5.9
Cook Paint & Varnish	126	12.0	10.8	1	-7.0	4.4	15.3	3.5	438.3	2338	1.6
De Soto	331	14.1	7.6	14	18.5	12.2	10.8	3.7	89.0	2071	NA
GAF	943	10.5	10.1	27	-5.6	12.0	1.1	1.3	45.1	640	NA
Guardsman Chemicals	49	20.4	14.3	2	22.7	1.8	19.4	3.8	122.3	2317	2.3
Ideal Basic Industries	345	16.3	10.6	35	6.5	1.6	58.9	0.5	4.8	416	0.3
Interspace	263	-1.2	8.0	15	17.3	1.2	31.3	0.4	8.3	117	NA
Johns-Manville	1461	11.7	11.9	103	13.6	12.2	5.6	0.8	11.9	479	-0.7
Masco	451	6.5	21.9	50	24.5	8.1	5.3	1.8	16.3	1081	NA
Masonite	445	15.3	8.9	31	-3.5	3.3	64.5	0.8	10.8	413	NA
National Gypsum	748	22.0	6.7	37	3.2	1.5	6.4	0.2	4.0	111	-3.1
Owens-Corning Fiberglas	1480	37.2	16.3	113	30.3	19.9	30.7	1.3	17.7	904	2.9
Pratt & Lambert	62	5.0	7.2	2	-1.5	1.3	6.5	1.6	84.9	1182	-2.9
Reliance Universal	139	15.5	11.2	4	-4.2	4.8	13.6	3.5	135.5	2644	-1.4
H. H. Robertson	329	0.6	3.2	9	5.1	3.6	5.1	1.1	41.5	531	-4.9
Sherwin-Williams	1036	8.8	9.9	-8	NA	9.0	-3.4	0.9	-109.7	458	-2.2
U. S. Gypsum	1177	22.2	10.4	60	4.9	7.5	16.0	0.6	12.6	370	-0.4
Wallace-Murray	448	43.6	14.8	23	31.7	4.7	17.5	1.0	20.8	452	NA
Jim Walter	1422	11.7	6.0	79	9.5	5.0	2.6	0.3	6.2	198	-2.1
Weyerhaeuser	3283	14.4	8.7	304	-1.7	48.3	62.6	1.4	15.2	964	0.2
Industry composite	17409	16.3	10.8	1035	5.7	167.2	15.4	1.0	16.2	564	0.3
CHEMICALS											
Air Products & Chemicals	947	15.8	23.4	68	40.5	24.1	28.0	2.5	35.6	1757	8.6
Akzona	809	11.0	2.5	8	-38.7	19.7	11.2	2.4	261.8	1268	-4.3
Allied Chemical	2923	11.2	13.9	138	7.7	53.4	28.3	1.8	38.6	1625	-0.1
American Cyanamid	2412	15.2	12.2	139	1.5	96.4	15.8	4.0	69.1	2203	NA
Betz Laboratories	148	15.0	21.6	15	0.8	5.0	25.4	3.4	33.2	2793	NA
Cabot	575	24.7	15.4	40	14.5	14.8	11.5	2.6	37.2	2651	-4.1
Celanese	2320	9.3	6.6	70	-4.8	77.0	10.0	3.3	110.0	2399	-3.2
Church & Dwight	99	-3.2	24.0	5	17.2	3.0	-10.3	3.0	64.9	5392	8.0
Dexter	316	23.8	20.5	19	25.8	9.8	22.8	3.1	53.1	2072	NA
Diamond Shamrock	1530	12.8	22.7	162	35.2	29.3	21.7	1.9	18.1	2595	5.1
Diversey	131	10.9	14.5	4	11.0	2.2	15.5	1.7	54.5	618	2.5
Dow Chemical	6234	10.3	16.8	556	16.4	203.3	8.5	3.3	36.6	3822	1.8
Du Pont	9435	12.8	11.7	545	-0.2	366.8	4.1	3.9	67.3	2793	0.6
Economics Laboratory	359	7.0	17.6	23	19.1	7.3	10.9	2.0	31.2	1288	88
Essex Chemical	77	21.5	16.4	4	28.9	1.4	4.8	1.9	35.1	2165	NA
Ethyl	1282	12.9	19.2	78	9.7	27.6	11.3	2.2	35.4	1725	NA
Ferro	420	11.6	10.3	21	0.3	11.4	14.7	2.7	54.7	1402	2.6
H. B. Fuller	193	14.9	19.8	6	13.7	1.4	19.1	0.7	22.2	457	10.6
W. R. Grace	3976	9.6	6.8	140	11.7	32.0	13.2	0.8	22.8	505	-4.7
Great Lakes Chemical	68	20.0	31.6	11	32.2	2.3	24.3	3.3	20.2	NA	NA
Grow Chemical	177	78.0	21.1	4	37.8	3.9	42.2	2.2	102.6	1773	11.4
Hercules	1698	6.4	8.5	58	-7.4	37.4	5.6	2.2	64.6	1557	0.7
Intl. Flavors & Fragrances	314	14.6	14.9	46	11.4	19.6	21.9	6.2	42.9	5891	3.7
Koppers	1356	14.0	16.4	66	21.5	11.5	8.4	0.8	17.3	632	3.7
Lawter Chemicals	48	12.5	9.4	8	13.2	0.8	12.8	1.7	9.7	2866	-1.7
Liquid Air of North America	285	7.1	12.2	20	16.9	1.1	31.3	0.4	5.3	276	NA
Lubrizol	507	10.9	14.7	58	9.7	19.2	13.0	3.8	33.1	5306	3.4
Monsanto	4595	7.6	13.9	276	4.3	132.3	15.7	2.9	48.0	2151	1.3
Morton-Norwich Products	609	8.1	12.1	32	-5.1	16.5	5.8	2.7	52.1	1516	-2.1
NL Industries	1587	9.4	0.8	66	7.2	18.0	20.0	1.1	27.1	732	NA
Nalco Chemical	446	15.6	19.2	50	20.5	14.6	17.7	3.3	29.1	3516	6.8
National Distillers & Chemical	1587	5.5	6.3	85	3.4	6.5	8.3	0.4	7.6	496	NA
National Starch & Chemical	371	9.3	14.1	26	11.6	7.4	18.4	2.0	28.2	1920	NA
New England Nuclear	41	18.1	24.0	4	15.0	2.6	37.7	6.5	67.0	2920	18.6
Olin	1473	7.0	9.9	78	29.4	25.1	1.5	1.7	32.1	1140	NA
Oakite	52	6.9	11.1	3	9.1	0.9	4.7	1.8	27.5	1052	1.2
PPG Industries	2506	11.1	13.5	92	5.1	60.6	7.6	2.4	66.1	1656	-1.2
Pantasote	119	17.1	5.7	2	2.2	1.7	21.4	1.4	82.4	850	-9.0
Pennwalt	835	7.4	12.8	42	18.7	20.9	11.5	2.5	50.1	1503	1.1
Petrolite	144	16.9	20.8	16	28.2	4.1	6.1	2.9	25.6	2509	NA

R&D SPENDING: 1977

COMPANY	SALES: 1977 MILLIONS OF DOLLARS	SALES: PERCENT CHANGE FROM 1976	SALES: PERCENT AVERAGE ANNUAL CHANGE	PROFITS: 1977 MILLIONS OF DOLLARS	PROFITS: PERCENT AVERAGE ANNUAL CHANGE	RESEARCH & DEVELOPMENT EXPENSE: 1977 MILLIONS OF DOLLARS	RESEARCH & DEVELOPMENT EXPENSE: PERCENT CHANGE FROM 1976	RESEARCH & DEVELOPMENT EXPENSE: PERCENT OF SALES	RESEARCH & DEVELOPMENT EXPENSE: PERCENT OF PROFITS	RESEARCH & DEVELOPMENT EXPENSE: DOLLARS PER EMPLOYEE	EMPLOYMENT: PERCENT AVERAGE ANNUAL CHANGE
Products Res. & Chem.	47	15.9	11.7	2	2.2	1.6	45.8	3.5	79.5	2474	-0.4
Reichhold Chemicals	674	15.2	20.3	14	-0.4	5.3	9.1	0.8	38.9	815	13.1
Rohm & Haas	1124	10.9	13.4	46	-9.3	45.4	6.5	4.0	99.5	3469	-0.3
SCM	1378	3.4	8.1	37	16.5	16.5	17.9	1.2	44.1	647	-2.5
Stauffer Chemical	1233	12.1	17.6	116	24.7	32.5	12.5	2.6	28.0	2501	2.9
Stepan Chemical	109	11.4	9.0	6	12.5	3.2	21.7	3.0	67.8	4247	3.4
Sun Chemical	338	15.7	6.9	15	25.3	6.7	21.8	2.0	45.2	1340	NA
Texasgulf	483	0.4	4.1	46	-17.1	2.2	1.3	0.5	4.8	415	8.1
Tremco	76	11.0	12.5	5	16.5	1.5	7.1	2.0	31.2	1345	0.0
Union Carbide	7036	10.9	14.3	385	3.5	155.8	9.4	2.2	40.5	1371	2.3
Virginia Chemicals	104	5.2	19.5	3	15.8	1.6	6.5	1.5	54.6	1734	5.9
Industry composite	65602	10.8	12.4	3759	6.8	1665.3	10.1	2.5	44.3	1833	1.2

COMPUTERS

COMPANY	SALES: 1977 MILLIONS OF DOLLARS	SALES: PERCENT CHANGE FROM 1976	SALES: PERCENT AVERAGE ANNUAL CHANGE	PROFITS: 1977 MILLIONS OF DOLLARS	PROFITS: PERCENT AVERAGE ANNUAL CHANGE	R&D: 1977 MILLIONS OF DOLLARS	R&D: PERCENT CHANGE FROM 1976	R&D: PERCENT OF SALES	R&D: PERCENT OF PROFITS	R&D: DOLLARS PER EMPLOYEE	EMPLOYMENT: PERCENT AVERAGE ANNUAL CHANGE
Amdahl	189	103.4	NA	27	NA	16.7	78.9	8.8	62.6	8679	NA
Applied Digital Data Systems	32	35.5	67.4	5	91.2	0.6	37.7	1.8	10.7	1160	NA
Applied Magnetics	67	5.7	6.1	-4	NA	2.8	17.9	4.2	-78.9	1013	-0.5
Burroughs	2091	11.8	13.0	215	18.7	122.4	13.4	5.9	56.9	2386	3.5
California Computer Products	117	3.2	7.2	-2	NA	8.6	-15.0	7.3	-451.9	3512	-7.3
Centronics Data Computer	57	10.4	21.4	13	23.1	3.6	27.8	6.4	29.0	2703	39.8
Control Data	1493	12.2	12.1	62	1.4	73.1	24.3	4.9	117.2	1592	0.0
Data General	255	42.5	42.8	29	43.0	26.1	41.8	10.2	91.2	3033	42.4
Datapoint	103	43.0	51.7	8	62.4	6.4	58.6	6.2	75.8	2325	42.6
Dataproducts	115	35.5	18.5	12	51.1	7.9	68.1	6.9	64.9	2394	NA
Digital Equipment	1059	43.8	39.4	109	42.8	79.7	36.5	7.5	73.5	2218	27.0
Electronic Associates	26	11.6	-8.6	0	-65.1	0.9	-56.4	3.4	6471.4	1262	-17.5
Electronic Memories & Magnetics	109	19.0	-1.3	5	10.5	6.8	45.0	6.3	145.3	1668	-13.8
General Automation	84	19.4	24.4	-1	NA	5.1	7.1	6.1	353.9	2584	24.8
Honeywell	2911	16.7	8.3	134	12.6	152.3	21.3	5.2	113.4	2009	-2.4
IBM	18133	11.2	13.3	2719	14.5	1142.0	12.8	6.3	42.0	3662	3.0
Memorex	450	30.6	26.2	34	NA	19.2	37.8	4.3	56.4	2178	11.2
Mohawk Data Sciences	146	-9.7	0.0	3	NA	5.1	16.3	3.5	191.4	1365	NA
NCR	2522	9.0	8.5	144	15.2	118.1	25.3	4.7	82.2	1845	-6.6
Pertec Computer	95	96.9	40.5	5	21.2	7.3	121.3	7.7	156.0	3487	28.9
Sperry Rand	3270	2.1	10.2	157	16.0	168.3	5.9	5.1	107.3	1965	-0.6
Storage Technology	162	33.3	28.0	11	25.6	9.2	17.0	5.6	80.1	2296	29.1
Systems Engineering Labs.	31	53.8	15.8	1	NA	3.7	64.0	12.1	550.4	4917	1.9
Telex	112	10.3	12.5	3	NA	2.8	31.1	2.5	86.2	691	0.5
Wang Laboratories	134	38.7	28.4	9	25.6	6.6	53.6	4.9	71.8	2047	NA
Industry composite	33764	12.5	12.9	3700	15.5	1995.4	16.3	5.9	53.9	2752	1.0

CONGLOMERATES

COMPANY	SALES: 1977 MILLIONS OF DOLLARS	SALES: PERCENT CHANGE FROM 1976	SALES: PERCENT AVERAGE ANNUAL CHANGE	PROFITS: 1977 MILLIONS OF DOLLARS	PROFITS: PERCENT AVERAGE ANNUAL CHANGE	R&D: 1977 MILLIONS OF DOLLARS	R&D: PERCENT CHANGE FROM 1976	R&D: PERCENT OF SALES	R&D: PERCENT OF PROFITS	R&D: DOLLARS PER EMPLOYEE	EMPLOYMENT: PERCENT AVERAGE ANNUAL CHANGE
Avco	1538	14.3	6.7	100	40.3	13.4	9.6	0.9	13.4	559	NA
Chromalloy American	1135	21.1	12.9	38	10.4	3.6	38.1	0.3	9.6	134	NA
Colt Industries	1525	13.4	12.0	69	16.5	17.7	14.2	1.2	25.4	574	NA
Greyhound	3841	1.0	2.6	83	1.9	12.6	0.7	0.3	15.3	244	-1.5
IC Industries	1673	10.9	11.1	79	7.2	8.7	6.2	0.5	11.1	203	1.7
ITT	13146	11.5	5.8	562	1.8	280.0	13.8	2.1	49.8	600	NA
Walter Kidde	1475	19.6	9.7	57	10.6	11.9	29.3	0.8	21.0	290	2.3
LTV	4703	5.7	2.1	-23	NA	19.1	-34.9	0.4	-83.6	363	-5.7
Litton Industries	3441	2.6	8.8	56	-2.4	68.6	21.0	2.0	122.7	730	-3.6
Martin Marietta	1440	18.7	4.7	102	12.2	6.0	20.0	0.4	5.9	238	-5.1
Signal	2964	20.9	20.3	102	18.2	113.6	35.8	3.8	112.0	2465	9.7
Studebaker-Worthington	1272	8.5	15.5	69	43.0	19.7	11.3	1.5	28.7	843	0.9
Teledyne	2210	14.0	10.1	194	43.7	28.9	17.5	1.3	14.9	593	-1.9
Textron	2802	6.7	10.9	137	8.0	61.9	14.8	2.2	45.2	967	-0.2
Industry composite	43365	10.2	7.5	1624	10.9	665.8	17.8	1.5	41.0	722	-1.2

R&D SPENDING: 1977

COMPANY	SALES: 1977 MILLIONS OF DOLLARS	SALES: PERCENT CHANGE FROM 1976	SALES: PERCENT AVERAGE ANNUAL CHANGE	PROFITS: 1977 MILLIONS OF DOLLARS	PROFITS: PERCENT AVERAGE ANNUAL CHANGE	RESEARCH & DEVELOPMENT EXPENSE: 1977 MILLIONS OF DOLLARS	R&D: PERCENT CHANGE FROM 1976	R&D: PERCENT OF SALES	R&D: PERCENT OF PROFITS	R&D: DOLLARS PER EMPLOYEE	EMPLOYMENT: PERCENT AVERAGE ANNUAL CHANGE
CONTAINERS											
American Can	3442	15.1	8.3	109	10.5	36.5	7.7	1.1	33.6	748	-3.5
Anchor Hocking	641	2.0	16.7	30	15.8	7.3	12.3	1.1	24.3	435	3.7
Ball	448	12.9	18.3	16	20.6	4.7	10.1	1.1	30.2	570	NA
Continental Group	3661	5.9	8.8	144	8.9	37.7	-6.5	1.0	26.2	655	-2.8
Maryland Cup	374	20.7	18.2	18	16.9	2.0	11.1	0.5	11.4	222	8.8
Owens Illinois	2767	7.6	10.4	91	6.7	31.2	-8.1	1.1	34.1	460	0.2
Rexham	111	2.1	8.5	6	21.8	1.1	31.6	1.0	18.5	531	-3.6
Industry composite	11445	9.4	10.0	413	10.0	120.5	-7.6	1.1	29.2	573	3.3
DRUGS: Medicines, medical supplies											
Abbott Laboratories	1245	14.8	19.0	118	27.1	66.7	11.9	5.4	56.6	2554	6.2
Allergan Pharmaceuticals	52	18.2	27.0	7	61.5	3.6	20.3	7.0	49.7	3284	13.6
American Home Products	2685	8.6	10.6	306	11.3	65.9	9.6	2.5	21.5	1345	2.1
American Hospital Supply	1488	10.8	15.2	78	16.7	22.8	30.5	1.5	29.2	811	6.8
American Sterilizer	150	-0.6	11.3	4	-9.7	4.7	16.6	3.1	113.1	1419	2.2
Baxter Travenol Laboratories	844	23.9	23.5	75	28.3	37.1	9.8	4.4	49.4	1242	15.7
Becton Dickinson	596	14.4	14.0	47	17.5	26.0	25.7	4.4	55.9	1468	3.2
Cooper Laboratories	111	12.3	12.2	11	NA	5.0	42.2	4.5	47.1	1923	NA
Hycel	42	16.8	27.0	2	74.6	2.7	23.4	6.5	139.1	3277	NA
ICN Pharmaceuticals	84	-4.5	-5.1	-1	NA	1.8	-39.6	2.1	-262.5	716	-16.4
Johnson & Johnson	2914	15.5	15.6	247	13.4	131.8	17.1	4.5	53.3	2179	6.4
Eli Lilly	1518	11.6	11.6	219	8.0	124.6	9.3	8.2	57.0	5236	-0.1
Mallinckrodt	313	12.8	17.0	27	22.6	11.1	24.5	3.5	40.7	2562	8.8
Marion Laboratories	100	23.9	12.9	11	-2.3	5.9	22.0	5.9	55.4	3450	NA
Merck	1724	10.5	11.7	278	10.9	144.9	8.3	8.4	52.2	5157	2.5
Pfizer	2032	7.7	11.8	175	9.7	98.3	11.6	4.8	56.0	2445	NA
Richardson-Merrell	836	12.1	13.5	57	6.5	33.9	6.8	4.1	59.2	2258	1.8
A. H. Robins	307	7.6	13.5	27	0.9	16.1	26.5	5.3	60.1	2929	6.0
Rorer Group	186	10.0	14.5	21	8.3	5.2	-4.1	2.8	24.9	1418	NA
Schering-Plough	941	8.0	11.4	167	12.2	58.6	6.7	6.2	35.1	3425	5.5
G.D. Searle	750	13.5	14.5	35	-10.0	52.6	11.8	7.0	148.5	2507	NA
Smithkline	780	15.9	14.9	89	13.5	61.8	12.8	7.9	69.2	4082	5.9
Squibb	1342	10.5	10.9	113	8.9	54.5	9.8	4.1	48.4	1557	1.5
Sterling Drug	1184	8.0	7.9	86	2.1	39.0	7.6	3.3	45.5	1427	1.2
Upjohn	1134	10.6	14.8	92	7.2	102.3	10.5	9.0	111.7	5431	7.1
Warner-Lambert	2543	8.2	11.0	188	5.9	80.7	2.3	3.2	43.0	1392	0.3
Industry composite	25902	11.2	12.9	2477	10.4	1257.4	9.9	4.9	50.8	2345	4.2
ELECTRICAL											
Bunker Ramo	341	7.8	3.3	10	28.7	4.8	33.3	1.4	46.4	495	-4.5
Crouse-Hinds	284	14.8	27.1	19	26.9	3.8	7.8	1.3	20.3	472	19.6
Cutler-Hammer	517	15.5	10.6	24	10.7	17.1	16.8	3.3	71.2	1140	NA
Echlin Mfg.	239	16.4	13.6	16	17.5	1.6	47.2	0.7	10.0	270	NA
Electronics Corp. of America	33	2.1	4.1	3	14.7	1.4	9.6	4.2	51.9	1586	-7.4
Eltra	922	12.9	7.3	43	7.0	15.5	19.2	1.7	36.5	710	-3.9
Emerson Electric	1809	18.9	12.3	142	13.6	37.0	19.4	2.0	26.0	863	5.0
Federal Signal	81	22.7	7.9	3	12.0	1.0	35.8	1.3	30.5	468	-0.2
General Electric	17519	11.6	9.3	1088.	13.6	463.5	12.6	2.6	42.6	1207	-0.1
Globe-Union	392	35.4	11.0	23	35.3	5.7	22.6	1.5	24.6	611	-3.1
Gould	1620	32.2	23.6	94	37.1	59.6	37.1	3.7	63.6	1604	13.0
Joslyn Mfg. & Supply	166	10.7	0.1	5	-8.7	1.5	19.3	0.9	31.7	500	[illegible]
Lightolier	70	15.5	5.2	1	1.9	2.2	16.6	3.1	181.2	1126	[illegible]
McGraw-Edison	1044	3.7	5.9	57	22.4	7.4	15.3	0.7	13.0	310	[illegible]
Medtronic	148	14.1	30.0	15	31.5	11.9	0.8	8.0	81.5	3500	[illegible]
Moog	76	25.6	15.2	• 2	1.4	2.3	-5.2	3.0	116.5	1111	[illegible]

R&D SPENDING: 1977

COMPANY	SALES			PROFITS		RESEARCH & DEVELOPMENT EXPENSE					EMPLOYMENT
	1977 MILLIONS OF DOLLARS	PERCENT CHANGE FROM 1976	PERCENT AVERAGE ANNUAL CHANGE	1977 MILLIONS OF DOLLARS	PERCENT AVERAGE ANNUAL CHANGE	1977 MILLIONS OF DOLLARS	PERCENT CHANGE FROM 1976	PERCENT OF SALES	PERCENT OF PROFITS	DOLLARS PER EMPLOYEE	PERCENT AVERAGE ANNUAL CHANGE
North American Philips	1917	11.2	27.1	81	19.3	30.0	19.0	1.6	40.0	865	NA
Ohio Brass	80	1.7	-0.4	5	59.6	3.2	25.2	3.5	[illegible]	605	-8.4
Platronics	49	43.8	26.6	5	24.8	3.2	37.8	6.5	61.1	2778	22.0
RCA	5681	10.4	8.3	247	11.0	126.5	13.0	2.2	51.2	1140	-2.6
RTE	133	-65.8	11.7	-9	48.5	4.8	32.7	3.6	51.0	625	6.4
Raychem	177	3.6	20.0	12	-21.5	11.7	-11.4	6.6	94.0	2438	11.7
Reliance Electric	629	16.5	10.8	54	19.1	20.3	6.9	3.7	38.6	1484	NA
Square D	611	15.8	8.9	59	14.1	10.0	11.6	1.6	17.0	557	NA
Thomas & Betts	158	23.4	9.6	21	9.8	7.4	30.3	4.7	35.6	2019	1.8
Thomas Industries	167	27.7	8.1	8	9.8	-2.0	40.9	1.2	25.6	513	-1.1
Westinghouse Electric	6138	-0.1	4.4	271	13.4	132.0	40.4	2.2	48.7	934	-5.7
Industry composite	41400	11.1	8.6	2296	14.4	991.5	12.2	2.4	43.2	2067	-0.7
ELECTRONICS											
AVX	44	31.8	9.4	3	18.8	0.8	-65.9	1.9	30.4	344	NA
Altec	34	-0.2	7.4	0	NA	0.6	27.4	1.8	-147.7	438	NA
Ambac Industries	234	14.9	8.6	17	23.0	10.4	26.8	4.4	62.1	1689	-1.8
AMP	633	21.3	9.5	76	11.5	58.0	23.4	9.2	76.4	3847	-3.1
Ampex	284	11.4	5.3	9	69.7	16.5	3.3	5.8	188.0	1530	NA
Applied Devices	25	12.3	26.0	1	37.4	0.4	83.6	1.6	33.3	817	17.2
Automatic Radio Mfg.	69	-11.2	13.4	-2	NA	0.7	10.6	1.0	-33.2	824	NA
Aydin	51	21.3	15.7	3	23.0	0.6	21.1	1.1	18.3	512	3.8
Belden	211	12.8	7.1	7	8.2	2.6	17.4	1.3	36.1	886	-1.2
Burndy	155	18.4	5.0	12	16.7	5.9	4.1	3.8	49.3	1399	-3.1
CTS	154	-2.3	3.8	12	3.4	5.5	4.7	3.2	64.7	802	-1.6
Conrac	133	9.3	18.8	6	23.8	2.2	9.3	1.7	34.2	737	4.4
Duro-Test	49	3.2	4.1	4	3.8	0.9	12.7	1.9	26.7	905	-1.5
EG&G	376	40.9	23.4	13	26.1	6.9	7.8	1.8	52.8	507	NA
E-Systems	347	8.6	21.8	19	56.3	12.9	23.0	3.7	68.0	1316	14.9
EDO	67	5.0	10.2	2	32.0	1.8	35.8	2.6	73.0	879	0.9
Electro Audio Dynamics	56	19.5	9.1	2	-10.7	1.0	11.5	1.8	60.7	601	NA
Executone	33	25.8	10.3	1	6.6	0.6	-10.8	1.8	71.4	884	-6.5
General Cable	621	77.7	1.6	20	-2.4	7.6	146.2	1.2	37.3	475	15.5
Harris	646	25.8	12.8	40	19.4	25.9	29.5	4.0	64.7	1579	NA
Hazeltine	96	7.1	4.1	4	42.5	2.6	17.7	2.6	70.3	1117	NA
High Voltage Engineering	47	20.4	9.8	2	-2.6	1.4	10.8	3.0	89.2	1069	NA
King Radio	58	20.2	7.4	3	-5.4	4.6	13.0	7.9	138.2	2225	6.6
Lear Siegler	920	32.5	9.0	37	20.2	11.6	58.9	1.3	31.3	475	-1.9
Loral	97	43.3	29.5	7	84.2	2.7	21.2	2.8	37.8	1160	14.2
Lynch Communication Systems	25	6.9	6.5	2	-5.0	0.8	-11.5	3.3	52.8	954	-0.6
M A Com	66	8.0	10.9	4	12.1	1.9	20.9	3.0	50.0	867	3.6
P. R. Mallory	342	15.0	14.2	14	20.4	4.2	32.4	1.2	30.9	872	3.0
Oak Industries	161	4.8	6.1	2	-24.0	4.3	8.5	2.9	284.0	672	-3.1
Raytheon	2818	14.4	14.9	113	24.4	51.7	10.2	1.8	45.6	894	2.8
Sanders Associates	147	-13.5	1.5	8	12.9	5.3	10.4	3.6	70.1	1243	-5.6
Scientific-Atlanta	51	12.5	27.0	3	42.0	2.2	30.8	4.3	81.8	1410	16.2
Tracor	156	21.9	18.3	6	35.6	3.5	21.8	2.3	57.5	618	6.5
Unitrode	39	26.8	7.7	3	9.6	1.3	9.4	3.4	39.0	1094	-1.2
Varian Associates	352	14.7	11.7	12	19.4	22.1	15.7	6.3	186.4	2162	3.6
Varo	75	1.4	20.7	10	70.5	1.2	4.4	1.7	12.5	727	1.3
Vernitron	72	30.4	12.6	4	20.4	1.2	21.0	1.7	33.9	NA	NA
Watkins-Johnson	90	25.1	12.3	5	3.0	5.9	33.9	6.5	107.8	2165	8.3
Whitaker Cable	51	13.2	1.7	1	-25.3	1.2	NA	2.3	223.4	470	-9.2
Industry composite	9877	17.9	10.9	483	17.5	292.5	16.1	3.0	60.6	1178	1.2
FOOD, BEVERAGES											
AZL Resources	100	-0.9	-1.8	-6	NA	1.0	-3.3	1.0	-15.9	816	NA
Amstar	950	-15.0	7.6	28	17.3	2.9	39.1	0.3	10.2	843	6.0
Anderson Clayton	948	24.8	4.9	39	18.6	3.0	6.4	0.3	7.7	193	-6.8
Borden	3481	3.0	6.8	127	15.1	16.3	10.1	0.5	12.8	431	-4.5
CPC International	2870	6.5	9.4	133	14.5	25.5	4.1	0.9	19.2	607	-0.6
Campbell Soup	1769	8.2	8.6	107	8.1	15.4	11.8	0.9	14.4	465	0.1
Carnation	2335	7.7	11.2	109	13.0	9.5	30.1	0.4	8.7	428	4.2
Central Soya	2177	18.5	11.5	12	-12.3	4.4	33.3	0.2	35.6	464	-2.4

R&D SPENDING: 1977

COMPANY	SALES: 1977 MILLIONS OF DOLLARS	SALES: PERCENT CHANGE FROM 1976	SALES: PERCENT AVERAGE ANNUAL CHANGE	PROFITS: 1977 MILLIONS OF DOLLARS	PROFITS: PERCENT AVERAGE ANNUAL CHANGE	RESEARCH & DEVELOPMENT EXPENSE: 1977 MILLIONS OF DOLLARS	R&D: PERCENT CHANGE FROM 1976	R&D: PERCENT OF SALES	R&D: PERCENT OF PROFITS	R&D: DOLLARS PER EMPLOYEE	EMPLOYMENT: PERCENT AVERAGE ANNUAL CHANGE
Coca-Cola	3560	15.0	12.1	326	-15.6	11.1	20.8	0.3	3.4	321	NA
Consolidated Foods	2892	5.0	9.0	68	3.9	7.0	17.8	0.2	8.0	93	1.6
DeKalb AgResearch	384	6.3	19.3	37	19.1	8.7	34.2	2.3	23.5	2494	NA
Del Monte	1484	3.7	12.9	51	17.7	11.0	11.1	0.7	21.6	145	2.1
Esmark	5250	-0.4	7.4	67	8.6	9.4	-8.0	0.2	14.0	209	NA
General Foods	4910	23.4	15.0	177	12.5	48.9	31.7	1.0	28.1	1039	-0.1
General Mills	2909	10.0	15.0	117	15.4	28.9	16.3	1.0	25.5	484	10.5
Gerber Products	405	8.6	10.7	22	15.8	3.5	11.2	0.9	15.9	407	5.1
Green Giant	426	8.4	10.0	11	-5.3	2.6	21.7	0.6	23.4	337	6.3
H. J. Heinz	1869	6.8	13.8	84	14.1	9.4	-1.9	0.5	11.2	285	NA
Hershey Foods	671	11.5	11.0	36	27.1	2.7	20.5	0.4	7.5	351	-3.3
Holly Sugar	178	-19.1	20.1	3	16.2	1.6	-7.3	0.9	54.0	643	NA
Geo. A. Hormel	1106	1.0	7.6	22	22.2	2.0	NA	0.2	9.3	233	0.0
International Multifoods	847	5.8	10.7	20	18.3	1.6	4.6	0.2	8.0	203	2.8
Kellogg	1533	10.7	12.8	138	22.2	7.7	2.7	0.5	5.5	377	2.3
Kraft	5239	5.3	8.9	154	12.3	16.0	23.1	0.3	10.4	341	-0.9
Oscar Mayer	1188	4.9	7.7	35	16.4	5.6	51.8	0.5	16.1	408	1.5
McCormick	355	16.9	17.3	15	17.3	1.7	24.8	0.5	11.6	344	7.6
Nabisco	2073	5.0	9.7	104	24.0	9.3	0.0	0.4	9.0	217	NA
Norton Simon	1808	3.9	9.2	102	12.7	8.4	17.6	0.5	8.2	193	NA
Pet	1064	5.3	8.2	27	5.8	1.0	0.0	0.1	3.7	545	-3.2
Pillsbury	1461	3.1	16.8	58	24.8	14.3	38.8	1.0	24.7	354	NA
Quaker Oats	1551	5.3	11.4	68	13.1	19.3	1.7	1.2	28.5	895	7.7
Ralston Purina	3756	10.7	10.2	143	16.8	17.6	7.3	0.5	12.3	263	11.9
Jos. Schlitz Brewing	937	-6.3	8.1	20	-18.0	1.8	0.0	0.2	8.9	222	NA
A. E. Staley Mfg.	1117	36.3	22.7	24	-37.4	4.8	2.1	0.4	19.6	1139	2.2
Standard Brands	2124	17.4	10.6	69	9.1	8.2	36.7	0.4	12.0	357	0.2
Topps Chewing Gum	55	-1.3	11.1	1	-6.8	0.8	34.6	1.5	71.8	647	1.8
Universal Foods	194	12.3	14.6	9	31.8	1.9	NA	1.0	21.7	1000	2.5
Wm. Wrigley Jr.	398	7.5	14.9	29	14.0	1.6	-19.5	0.4	5.4	275	4.3
Industry composite	66375	7.9	10.5	2606	10.6	348.4	16.0	0.5	13.4	363	2.4
FUELS											
Ashland Oil	4786	15.5	20.3	164	17.4	8.5	5.3	0.1	3.4	172	NA
Atlantic Richfield	10969	28.0	23.2	702	23.4	45.4	37.6	0.4	6.5	885	9.3
Cities Service	4388	10.7	20.7	210	9.9	10.0	-3.8	0.2	4.8	553	-2.6
Continental Oil	8700	9.3	17.0	381	15.8	27.4	15.6	0.3	7.2	634	2.9
Exxon	54126	4.8	15.6	2423	-1.6	230.0	13.9	0.4	9.5	1811	-2.1
Gulf Oil	17840	8.4	16.2	752	-3.8	70.0	9.4	0.4	9.3	1179	3.0
Kerr-McGee	2165	10.7	27.3	119	15.3	4.6	6.5	0.2	3.9	407	5.1
Marathon Oil	4252	21.0	22.8	197	10.3	12.7	13.4	0.3	6.4	949	12.5
Occidental Petroleum	6018	8.7	14.8	218	8.9	29.3	-10.2	0.5	13.4	912	0.8
Phillips Petroleum	6284	10.3	17.6	517	17.0	48.5	20.5	0.8	9.4	1709	-4.6
St. Joe Minerals	791	0.0	15.1	68	8.4	3.6	17.4	0.5	5.3	421	NA
Shell Oil	10112	9.6	17.9	735	18.7	91.0	3.4	0.9	12.4	2713	0.4
Standard Oil Co. of Calif.	20917	7.8	22.2	1016	2.0	83.3	9.4	0.4	8.2	2175	-1.4
Standard Oil (Ind.)	13020	4.1	17.9	1012	13.8	73.7	9.8	0.6	7.3	1579	-0.2
Standard Oil (Ohio)	3511	20.6	22.4	181	20.6	11.7	11.5	0.3	6.5	629	1.7
Sun	6418	19.1	27.3	362	8.9	23.0	-8.0	0.4	6.4	711	4.8
Superior Oil	545	23.5	20.9	63	6.4	3.6	18.1	0.7	5.8	1014	3.8
Texaco	27921	5.6	21.2	931	-10.9	52.0	0.0	0.2	5.6	736	-1.4
Tosco	1068	25.8	55.2	13	7.1	1.9	-8.1	0.2	15.4	620	NA
Union Oil Co. of California	5669	2.3	16.9	334	12.5	17.1	-0.6	0.3	5.1	1035	NA
Witco Chemical	632	11.7	11.5	25	6.4	9.2	13.6	1.5	37.3	1793	1.2
Industry composite	210132	8.6	18.7	10421	4.1	853.4	12.1	0.4	8.2	1225	1.8
[illegible]											
Ametek	299	23.9	9.9	17	16.3	4.8	23.1	1.6	27.9	780	1.0
Anken Industries	27	9.2	16.7	2	29.5	0.5	14.1	1.8	32.5	829	4.3
Badger Meter	54	16.1	9.2	3	9.7	1.1	-3.3	2.1	38.4	867	0.0
C. R. Bard	165	9.0	12.3	10	7.3	2.7	17.4	1.6	26.1	739	NA
Bausch & Lomb	378	8.3	11.7	25	20.6	11.6	8.4	3.1	46.5	1077	[illegible]
Beckman Instruments	[illegible]	17.9	14.5	16	28.0	22.4	25.9	7.8	136.7	2803	[illegible]
Bell & Howell	[illegible]	12.4	11.9	12	-5.2	25.2	15.6	5.1	213.5	1951	[illegible]
Bulova Watch	[illegible]	1.4	2.6	-7	NA	1.8	-7.0	0.9	-25.9	323	[illegible]

R&D SPENDING: 1977

COMPANY	SALES 1977 MILLIONS OF DOLLARS	SALES PERCENT CHANGE FROM 1976	SALES PERCENT AVERAGE ANNUAL CHANGE	PROFITS 1977 MILLIONS OF DOLLARS	PROFITS PERCENT AVERAGE ANNUAL CHANGE	RESEARCH & DEVELOPMENT EXPENSE 1977 MILLIONS OF DOLLARS	R&D PERCENT CHANGE FROM 1976	R&D PERCENT OF SALES	R&D PERCENT OF PROFITS	R&D DOLLARS PER EMPLOYEE	EMPLOYMENT PERCENT AVERAGE ANNUAL CHANGE
Dentsply International	189	38.4	21.7	6	-2.3	3.8	48.7	2.0	67.0	537	15.5
Esterline	127	27.4	7.6	3	17.7	2.5	22.5	1.9	84.2	684	NA
Fischer & Porter	133	1.2	11.6	4	31.0	6.5	38.6	4.9	146.8	1457	3.8
Fisher Scientific	268	19.0	16.3	9	47.6	2.6	6.5	1.0	29.4	677	4.9
John Fluke Mfg.	61	23.3	22.8	4	27.3	5.4	12.9	8.9	120.7	3473	NA
Foxboro	369	12.5	20.7	32	47.5	21.4	28.4	5.8	67.5	2176	NA
GCA	52	27.0	9.8	2	-9.9	2.5	-3.2	4.8	145.0	NA	NA
General Signal	876	9.7	12.5	48	17.3	24.5	1.5	2.8	51.1	1222	0.8
Hewlett-Packard	1360	22.3	18.2	122	19.9	125.4	16.5	9.2	103.2	3573	9.1
Philip A. Hunt Chemicals	74	14.1	8.7	6	-1.2	3.8	23.2	5.2	68.0	3554	2.1
Instron	29	16.9	8.8	1	5.2	2.3	86.2	7.9	249.8	3064	6.2
Itek	223	6.9	2.3	3	3.0	7.3	-7.0	3.3	262.5	1221	-5.9
Johnson Controls	373	15.4	10.6	24	42.1	7.5	24.8	2.0	31.4	640	4.4
Kollmorgen	97	17.2	8.0	6	16.9	3.0	27.7	3.1	53.8	1112	4.6
Leeds & Northrup	162	13.6	10.8	6	28.2	6.7	14.0	4.1	118.4	1356	0.7
Measurex	64	22.7	21.4	5	13.4	4.2	3.6	6.6	78.8	2885	29.4
Narco Scientific Industries	79	15.5	6.4	3	23.8	2.8	4.0	3.6	84.2	1663	NA
National Patent Development	55	0.8	36.1	0	-53.0	2.4	76.8	4.3	4251.8	1604	NA
Perkin-Elmer	432	21.9	14.1	27	10.4	24.7	23.5	5.7	93.0	2227	7.0
Puritan-Bennett	58	6.0	10.4	5	5.2	2.3	13.5	4.0	44.8	1747	2.9
Ranco	128	19.5	5.5	7	5.3	2.8	45.3	2.2	37.9	511	NA
Robertshaw Controls	269	8.9	9.7	9	2.8	6.3	12.0	2.3	72.2	596	1.6
Sybron	585	1.4	9.1	27	5.7	19.2	3.1	3.3	70.3	1243	NA
Systron-Donner	56	7.3	6.2	2	-4.0	2.6	-7.4	4.6	164.4	1490	-3.5
Talley Industries	371	7.0	7.2	12	7.2	3.2	0.4	0.9	27.6	321	0.6
Technicare	164	75.5	52.3	15	96.5	13.0	108.4	7.9	86.5	4818	21.7
Technicon	240	6.6	16.1	26	16.9	16.7	18.4	6.9	63.6	4170	NA
Tektronix	455	24.1	21.1	44	25.5	38.7	30.1	8.5	87.9	2641	10.3
Veeco Instruments	45	20.7	8.7	5	11.7	1.7	16.1	3.7	36.2	NA	NA
Industry composite	9302	14.8	13.1	539	17.7	435.8	19.6	4.7	80.8	1782	6.3
LEISURE TIME											
AMF	1229	9.6	5.5	43	-1.1	9.6	0.4	0.8	22.5	318	NA
Bally Mfg.	240	18.2	15.9	19	9.6	2.5	10.1	1.1	13.1	507	NA
Brunswick	1000	9.4	9.6	37	-0.2	24.9	6.4	2.5	67.2	984	0.9
Coleco Industries	137	17.4	16.0	2	10.2	4.1	112.9	3.0	245.9	1042	NA
Coleman	257	9.2	9.8	15	19.9	2.7	9.8	1.1	18.0	593	-2.3
Eastman Kodak	5967	9.7	10.0	643	0.0	351.1	4.7	5.9	54.6	2838	1.5
Executive Industries	58	-11.2	26.0	2	18.9	0.6	53.5	1.1	26.7	1018	6.8
Fleetwood Enterprises	566	44.3	13.3	15	7.8	5.2	28.0	0.9	34.5	595	1.7
Mattel	437	13.0	6.9	22	70.0	11.7	14.1	2.7	53.4	852	NA
Mego International	67	20.8	35.8	4	113.1	1.2	75.9	1.7	25.9	768	NA
Milton Bradley	198	3.1	8.0	13	20.5	7.4	29.4	3.7	57.6	1918	-2.6
Murray Ohio Mfg.	213	41.1	8.6	8	4.3	3.7	23.3	1.7	44.9	1213	-4.3
Norlin	239	12.4	8.1	9	4.5	1.8	0.0	0.8	20.0	300	0.8
Outboard Marine	630	11.8	9.9	30	-3.7	20.3	4.8	3.2	68.2	1471	NA
Polaroid	1062	11.8	11.7	92	24.4	88.9	14.7	8.4	96.4	5426	4.6
Tonka	89	-4.6	0.4	0	-34.7	1.6	31.6	1.8	412.5	698	1.5
Wurlitzer	83	9.2	-1.7	3	NA	2.0	3.5	2.4	77.9	627	-6.1
Industry composite	12471	11.7	9.7	958	2.5	539.4	7.7	4.3	56.3	2029	1.2
MACHINERY: Farm, construction											
Allis-Chalmers	1538	1.2	7.7	67	46.3	51.8	14.6	3.4	77.3	1918	-0.7
American Hoist & Derrick	367	-10.6	9.7	15	25.4	4.8	5.0	1.3	30.9	692	1.5
Bucyrus-Erie	547	12.8	31.8	52	35.2	14.4	5.1	2.6	27.5	2333	6.6
CMI	68	3.8	2.4	3	214.4	1.7	38.7	2.5	64.7	1970	NA
Caterpillar Tractor	5849	16.0	15.4	445	18.5	222.7	18.5	3.8	50.0	2835	4.3
Clark Equipment	1309	3.8	2.2	60	5.0	15.9	19.5	1.2	26.4	760	-8.0
Crutcher Resources	71	8.5	32.8	4	88.3	1.0	38.0	1.4	26.7	509	NA
Deere	3604	15.0	15.1	256	13.0	137.5	26.8	3.8	53.8	2346	4.[illegible]
FMC	2292	11.0	14.2	127	14.6	54.2	2.0	2.4	42.7	1228	NA
Hesston	142	-24.0	10.4	-9	NA	4.0	1.0	2.8	-43.2	1334	15.[illegible]
Koehring	362	5.6	4.9	11	4.9	7.7	8.0	2.1	73.3	1286	-11.1
Portec	145	22.1	15.5	4	11.0	1.9	11.8	1.3	47.8	664	5.9
Industry composite	16293	10.9	12.9	1034	17.1	517.6	17.1	3.2	50.0	2013	1.6

R&D SPENDING: 1977

COMPANY	SALES: 1977 MILLIONS OF DOLLARS	SALES: PERCENT CHANGE FROM 1976	SALES: PERCENT AVERAGE ANNUAL CHANGE	PROFITS: 1977 MILLIONS OF DOLLARS	PROFITS: PERCENT AVERAGE ANNUAL CHANGE	RESEARCH & DEVELOPMENT EXPENSE: 1977 MILLIONS OF DOLLARS	R&D: PERCENT CHANGE FROM 1976	R&D: PERCENT OF SALES	R&D: PERCENT OF PROFITS	R&D: DOLLARS PER EMPLOYEE	EMPLOYMENT: PERCENT AVERAGE ANNUAL CHANGE
MACHINERY: Machine tools, industrial, mining											
A-T-O	568	9.6	6.4	12	4.1	6.7	22.7	1.2	58.1	394	3.1
Acme-Cleveland	218	12.4	12.8	5	-12.4	2.1	17.5	1.0	44.3	385	1.3
American Air Filter	256	5.0	15.4	9	24.8	3.4	19.9	1.3	36.4	622	NA
Ansul	96	1.2	4.5	3	-14.6	1.2	1.7	1.3	46.7	652	0.1
Aro	64	14.7	7.7	6	9.1	1.0	5.6	1.5	17.1	528	-2.2
Black & Decker Mfg.	812	8.5	15.5	52	8.6	15.3	6.4	1.9	29.6	888	3.3
Briggs & Stratton	389	18.9	8.5	33	5.0	3.2	46.2	0.8	9.7	407	0.8
Brown & Sharpe Mfg.	109	18.0	5.5	4	-14.0	3.0	-2.2	2.7	77.3	840	NA
Chemineer	40	28.8	31.4	2	75.1	0.4	45.9	1.1	19.7	397	NA
Chicago Pneumatic Tool	302	11.1	4.3	7	-23.1	6.3	-4.4	2.1	88.2	659	NA
Cincinnati Milacron	532	18.6	7.4	21	18.6	14.9	13.7	2.8	71.4	1145	-1.5
Clausing	27	35.5	4.6	2	10.3	0.3	-26.1	1.1	16.1	799	-6.4
Combustion Engineering	2045	11.7	14.7	67	12.6	29.0	-1.4	1.4	43.2	648	5.7
Condec	223	-3.1	8.7	8	79.3	2.4	19.8	1.1	29.3	499	-3.2
Cooper Industries	679	22.4	19.6	54	30.4	2.0	-33.3	0.3	3.7	146	5.3
Crompton & Knowles	193	24.8	11.6	5	5.5	3.7	7.6	1.9	69.2	1208	4.0
Curtiss-Wright	310	-9.6	6.1	16	20.0	1.7	11.0	0.5	10.2	593	-5.9
Dynamics Corp. of America	120	12.1	12.4	5	45.3	1.0	-3.2	0.8	20.2	484	-7.7
Emhart	1199	8.4	55.3	59	42.3	24.1	11.3	2.0	40.6	739	26.7
Envirotech	459	13.1	29.2	17	34.1	11.0	53.3	2.4	63.4	1185	NA
Ex-Cell-O	447	7.3	6.7	29	14.5	9.2	13.5	2.1	31.8	940	-1.8
Foster Wheeler	1189	12.0	17.9	27	26.2	7.5	29.3	0.6	27.7	396	NA
Gardner-Denver	502	13.3	13.9	24	-6.6	7.1	8.2	1.4	30.1	593	NA
Giddings & Lewis	150	28.7	18.9	8	58.2	1.7	10.8	1.2	21.1	482	2.6
Goulds Pumps	174	16.7	27.7	16	40.1	1.5	37.5	0.9	9.3	487	13.6
Harnischfeger	471	6.1	24.1	22	32.1	12.7	24.5	2.7	58.1	1549	11.7
Hobart	478	11.1	10.0	25	4.0	6.4	17.8	1.3	25.9	.492	4.0
Ingersoll-Rand	2113	10.0	16.3	118	6.4	58.6	4.5	2.8	49.8	1243	NA
Ionics	29	18.7	18.0	2	30 1	0.9	24.9	3.2	60.3	1876	11.7
Joy Mfg.	678	7.5	21.1	48	41.7	7.4	-26.5	1.1	15.3	571	7.0
Kearney & Trecker	69	11.8	6.9	5	95.2	1.7	-6.2	2.5	36.4	1065	0.5
LFE	64	2.3	3.7	1	42.1	1.2	-9.3	1.9	110.1	577	NA
Leesona	101	-4.9	1.7	2	-17.6	4.3	-11.0	4.3	223.9	1388	-3.2
Lodge & Shipley	25	-10.5	13.7	1	9.1	0.4	7.4	1.4	53.6	704	NA
McNeil	178	1.2	7.1	5	-3.8	1.0	-3.6	0.5	20.0	221	-0.3
Midland-Ross	471	13.3	12.8	25	21.5	4.2	NA	0.9	16.6	424	0.7
Milton Roy	56	7.7	10.7	1	-6.6	2.0	26.8	3.5	139.1	1221	4.3
Omark Industries	138	31.9	10.3	9	-0.3	2.7	30.6	1.9	28.5	814	-1.5
Pall	67	19.2	20.9	8	62.2	1.8	15.3	2.7	23.0	1040	9.3
Parker-Hannifin	503	23.5	9.5	28	14.4	10.3	15.1	2.0	36.4	705	4.1
Peabody International	391	18.6	17.3	16	19.8	2.1	19.3	0.5	13.2	271	NA
Ransburg	41	24.4	2.5	6	0.5	1.3	30.4	3.1	21.8	1165	NA
Research-Cottrell	237	2.5	14.9	8	17.8	3.8	17.0	1.6	46.4	1572	6.0
Rexnord	744	17.2	9.8	44	26.5	7.3	21.1	1.0	16.6	447	NA
Riley	243	15.5	19.2	7	22.7	1.8	-25.9	0.8	26.4	530	5.6
Rockaway	25	-1.5	2.5	1	-4.0	0.3	3.1	1.3	22.3	528	-2.7
Selas Corp. of America	51	-15.9	24.7	1	7.9	0.7	0.1	1.4	57.9	1244	3.7
Stewart-Warner	292	6.6	4.2	19	8.9	8.3	-1.0	2.8	42.6	NA	NA
Sundstrand	650	9.2	14.1	35	29.6	22.8	-7.3	3.5	64.6	1594	1.3
Torin	73	25.8	13.1	3	0.1	2.5	19.0	3.4	97.2	1291	5.2
Twin Disc	116	-5.0	11.3	7	16.5	2.3	4.1	2.0	30.8	823	3.0
U. S. Filter	424	18.3	28.0	14	17.6	2.7	12.3	0.6	19.7	455	12.4
Warner & Swasey	262	4.2	4.6	12	0.6	5.5	-3.5	2.1	47.6	1037	-4.7
Wheelabrator-Frye	482	33.4	17.0	23	22.3	3.7	45.4	0.8	16.2	322	NA
Industry composite	20576	11.6	14.9	987	14.8	340.4	5.7	1.7	34.5	749	5.1
METALS & MINING											
Aluminum Co. of America	3417	16.6	10.3	195	12.1	52.0	8.3	1.5	26.6	1150	-1.1
Amax	1338	14.3	6.8	69	-8.7	17.0	4.7	1.3	24.6	1114	NA
Asarco	1046	-5.3	-2.4	-30	NA	4.9	10.6	0.5	-16.6	376	-3.1
Brush Wellman	101	3.7	6.8	8	1.8	2.5	12.5	2.5	31.7	1399	0.2
Cyprus Mines	327	6.4	-4.2	5	-40.2	3.3	-8.2	1.0	68.6	873	-6.5
Gulf Resources & Chemical	326	4.9	20.3	9	1.8	1.8	4.6	0.6	19.7	417	9.0
Harsco	683	15.1	13.2	43	19.2	1.1	49.5	0.2	2.6	81	-0.5
Kaiser Aluminum & Chemicals	2180	17.7	11.9	112	25.5	15.2	15.2	0.7	13.6	579	0.5

R&D SPENDING: 1977

COMPANY	SALES: 1977 MILLIONS OF DOLLARS	SALES: PERCENT CHANGE FROM 1976	SALES: PERCENT AVERAGE ANNUAL CHANGE	PROFITS: 1977 MILLIONS OF DOLLARS	PROFITS: PERCENT AVERAGE ANNUAL CHANGE	RESEARCH & DEVELOPMENT EXPENSE: 1977 MILLIONS OF DOLLARS	R&D: PERCENT CHANGE FROM 1976	R&D: PERCENT OF SALES	R&D: PERCENT OF PROFITS	R&D: DOLLARS PER EMPLOYEE	EMPLOYMENT: PERCENT AVERAGE ANNUAL CHANGE
Kennametal	165	20.8	12.7	15	6.5	4.7	-0.9	2.8	30.1	1148	5.7
Kennecott Copper	925	-3.2	-3.7	0	-59.9	13.6	-15.9	1.5	4592.3	798	NA
Revere Copper & Brass	598	19.9	3.6	10	5.1	1.4	-16.5	0.2	13.5	176	-3.5
Reynolds Metals	2353	12.9	10.7	86	12.6	23.3	4.0	1.0	27.0	656	-1.2
Triangle Industries	209	14.6	-1.8	-4	NA	1.9	8.3	0.9	-49.1	659	NA
	13666	11.8	7.1	520	-3.2	142.7	4.9	1.0	27.4	747	-0.3
MISCELLANEOUS MANUFACTURING											
ACF Industries	706	11.8	11.9	36	8.7	3.9	1.9	0.5	10.7	292	4.7
American Seating	75	-11.3	2.8	1	17.6	1.0	14.1	1.4	95.5	622	NA
American Standard	1792	8.3	3.1	88	24.7	17.4	8.4	1.0	19.7	376	NA
Amsted Industries	546	9.5	9.8	36	26.4	2.9	0.0	0.5	8.1	264	NA
Armstrong Cork	1089	11.0	7.6	40	-1.3	27.1	10.7	2.5	67.1	1172	-0.1
Bangor Punta	568	15.9	10.8	18	28.0	8.5	183.3	1.5	47.1	664	NA
Basic	67	1.2	2.4	4	13.3	1.3	3.6	1.9	30.5	836	-3.0
Borg-Warner	2032	9.1	6.2	104	13.1	50.5	14.3	2.5	48.6	1285	-3.2
Braun Engineering	48	21.8	17.3	3	11.0	1.3	23.8	2.7	50.4	3171	9.6
Butler Mfg.	361	18.3	9.5	19	3.6	3.0	-12.1	0.8	16.1	675	0.5
Carrier	1310	17.9	9.7	57	22.1	29.9	13.8	2.3	52.3	1196	NA
Cetec	43	6.4	12.3	1	24.2	1.5	-3.1	3.4	183.8	1931	-0.3
Compugraphic	130	36.4	28.0	10	28.1	3.7	25.7	2.8	38.1	1306	16.0
Congoleum	375	31.9	11.2	25	19.7	5.1	21.4	1.3	20.5	506	NA
Conroy	66	24.9	7.2	3	2.9	0.8	43.6	1.2	23.9	494	NA
Copeland	270	32.5	7.1	15	14.3	2.9	54.9	1.1	18.7	687	2.5
Corning Glass Works	1120	9.1	3.2	92	11.5	54.8	12.2	4.9	59.5	1809	-6.3
Dayco	573	16.2	8.9	14	13.1	7.6	15.5	1.3	56.1	653	-0.4
Fedders	324	11.1	-1.8	-13	NA	3.5	-1.3	1.1	-26.6	677	NA
General Dynamics	2901	13.6	15.0	103	30.4	34.2	42.2	1.2	33.1	467	3.9
General Refractories	344	5.4	8.8	-7	NA	4.3	-9.0	1.2	-57.9	534	-3.4
Hillenbrand Industries	150	14.9	11.9	13	5.4	1.4	2.9	0.9	10.1	402	7.1
Houdaille Industries	386	15.9	5.3	27	12.9	6.6	15.8	1.7	24.4	857	-2.2
Illinois Tool Works	293	16.6	7.6	27	5.8	4.8	17.7	1.6	17.2	629	-0.6
Kroehler Mfg.	153	-2.4	4.3	-4	NA	2.1	7.7	1.4	-51.0	412	NA
Mark Controls	100	45.7	15.7	8	112.4	1.0	96.0	1.0	13.0	226	10.7
Marley	243	5.1	25.1	19	40.5	1.5	23.4	0.6	7.8	379	12.8
Minnesota Mining & Mfg.	3980	13.3	11.3	413	7.7	177.0	12.4	4.4	42.9	2176	1.7
Mohasco	653	4.6	6.1	11	4.2	5.8	12.8	0.9	53.8	342	0.8
Monogram Industries	196	16.9	1.9	10	7.0	1.0	-32.8	0.5	11.0	260	-6.6
National-Standard	269	21.1	8.7	12	9.9	4.1	2.2	1.5	35.1	829	1.6
Norris Industries	570	14.9	7.7	42	25.3	2.3	54.3	0.4	5.6	228	NA
Norton	848	13.1	11.0	41	9.6	10.2	17.0	1.2	24.6	450	-1.0
P & F Industries	37	-1.4	-4.1	-8	NA	1.3	-76.5	3.6	-17.2	1649	NA
Parker Pen	348	147.6	34.6	13	24.6	2.0	-0.6	0.6	15.7	343	6.9
Plant Industries	61	2.9	11.2	0	NA	0.7	10.9	1.2	-220.8	564	NA
Plymouth Rubber	52	4.7	7.1	-2	NA	0.6	20.8	1.2	-27.0	671	-3.9
Polychrome	89	19.7	17.3	3	0.7	1.2	12.8	1.4	40.4	815	14.2
Premier Industrial	177	11.7	8.3	14	14.4	1.3	14.8	0.7	9.7	536	4.8
Raymond Industries	30	38.0	9.7	2	17.3	0.4	59.2	1.3	21.2	437	2.9
Richardson	151	8.5	4.7	6	3.0	2.7	18.5	1.8	45.7	1108	-4.5
Rogers	58	14.4	6.9	2	-2.1	1.6	13.0	2.8	97.6	976	2.7
Rubbermaid	226	21.6	17.1	17	21.2	3.0	16.1	1.3	17.5	766	4.9
SPS Technologies	175	10.9	0.7	-3	NA	2.1	6.4	1.2	-81.2	421	-2.5
Signode	498	11.8	8.7	30	6.9	4.8	21.3	1.0	15.9	736	NA
Skil	164	13.1	11.2	4	22.6	2.6	10.6	1.6	71.5	574	-0.6
Snap-On Tools	254	19.9	18.9	22	16.9	2.3	16.6	0.9	10.5	448	7.8
Stanadyne	291	26.1	7.5	15	5.9	1.7	-4.7	0.6	11.4	283	2.9
Stanley Works	640	13.0	9.5	33	16.7	5.0	19.3	0.8	15.2	316	1.8
L. S. Starrett	67	14.4	12.9	6	4.5	0.8	8.9	1.2	13.9	374	NA
Tecumseh Products	650	13.4	4.5	39	7.9	5.2	22.7	0.8	13.3	492	-2.1
Tokheim	73	4.6	17.2	6	96.6	1.9	7.9	2.5	33.9	1248	2.2
Trane	486	11.3	10.3	25	18.0	9.0	8.2	1.9	36.2	853	3.0
UMC Industries	219	5.4	2.0	10	-0.4	1.5	28.1	0.7	15.2	244	-4.2
VSI	171	15.1	9.9	10	7.3	1.2	21.4	0.7	11.8	328	2.8
Vermont American	138	30.1	25.9	9	38.5	1.9	40.7	1.4	19.7	536	11.4
Vulcan Materials	511	24.2	8.9	40	13.8	2.2	13.5	0.4	5.4	378	-0.6
Worcester Controls	51	22.8	21.4	3	-5.8	0.8	33.2	1.6	28.1	665	17.6
Industry composite	28199	13.9	9.1	1861	11.2	540.5	18.1	1.9	29.0	892	1.4

R&D SPENDING: 1977

COMPANY	SALES			PROFITS		RESEARCH & DEVELOPMENT EXPENSE					EMPLOYMENT
	1977 MILLIONS OF DOLLARS	PERCENT CHANGE FROM 1976	PERCENT AVERAGE ANNUAL CHANGE	1977 MILLIONS OF DOLLARS	PERCENT AVERAGE ANNUAL CHANGE	1977 MILLIONS OF DOLLARS	PERCENT CHANGE FROM 1976	PERCENT OF SALES	PERCENT OF PROFITS	DOLLARS PER EMPLOYEE	PERCENT AVERAGE ANNUAL CHANGE
OFFICE EQUIPMENT											
Addressograph-Multigraph	596	4.1	4.6	-14	NA	4.8	8.6	0.8	-34.4	248	-4.0
Barry Wright	58	21.2	8.9	3	18.4	1.1	9.9	1.9	32.5	864	0.4
A. B. Dick	329	7.2	9.0	7	-14.6	6.4	-13.5	1.9	89.2	869	2.8
Dictaphone	212	60.0	18.0	6	-3.0	2.9	-2.3	1.4	52.1	720	0.9
Diebold	191	5.8	-1.6	5	-18.7	3.7	61.0	2.0	76.8	715	-4.8
Dymo Industries	210	8.8	12.5	5	-6.6	6.5	6.4	3.1	137.8	1186	-0.2
Nashua	411	15.4	14.2	15	2.0	6.6	21.0	1.6	42.8	1072	3.3
Pitney-Bowes	606	12.4	11.6	37	15.5	12.3	8.3	2.0	33.8	662	1.6
Savin Business Machines	122	107.9	28.4	11	63.2	1.1	608.5	0.9	10.2	817	-1.9
Standard Register	190	12.1	7.8	9	6.5	2.6	4.3	1.4	29.0	660	-1.7
Xerox	5077	14.9	14.4	407	6.2	269.1	19.1	5.3	66.2	2588	5.9
Industry composite	8000	14.4	11.6	490	6.8	317.1	20.0	4.0	64.7	1795	2.6
OIL SERVICE & SUPPLY											
Baker International	709	28.3	26.7	60	45.2	8.6	32.4	1.2	14.2	619	13.8
Camco	46	21.4	18.9	1	NA	0.9	-6.3	1.9	58.1	657	7.9
Cameron Iron Works	435	3.0	27.6	31	36.0	5.5	22.2	1.3	17.9	660	10.1
Chicago Bridge & Iron	610	5.7	13.2	58	22.7	3.8	4.8	0.6	6.6	384	2.8
Dresser Industries	2539	13.7	25.6	185	45.8	22.2	3.3	0.9	12.0	418	11.6
Halliburton	5424	11.5	26.1	355	41.5	26.2	12.9	0.5	7.4	298	17.0
Hughes Tool	451	17.5	35.9	43	32.0	3.8	7.4	0.8	8.8	390	NA
J. Ray McDermott	1224	11.0	40.6	192	68.6	3.0	NA	0.2	1.6	155	26.3
Marathon Mfg.	306	21.0	22.8	17	10.3	1.4	-1.5	0.4	7.8	171	13.7
Schlumberger	2160	19.3	22.5	402	43.7	69.0	15.0	3.2	17.2	NA	NA
Sedco	343	3.6	31.2	51	31.9	3.0	67.9	0.9	5.9	252	20.4
Smith International	354	14.9	30.8	39	47.7	6.3	10.9	1.8	16.0	1083	12.2
Whitehall	29	16.1	1.0	1	3.4	0.5	56.0	1.8	42.6	376	-11.1
Industry composite	14630	14.9	25.8	1437	41.1	154.2	13.8	1.1	10.7	378	16.3
PAPER											
Bemis	636	4.5	4.3	17	1.7	5.6	7.5	0.9	33.3	415	-2.7
Consolidated Papers	333	13.4	15.5	26	14.1	2.2	13.2	0.7	8.3	437	2.0
Crown Zellerbach	2318	6.5	12.3	109	-1.8	10.0	8.7	0.4	9.1	311	NA
Dennison Mfg.	356	19.4	13.4	19	16.7	7.6	28.7	2.1	41.0	955	NA
P. H. Glatfelter	108	10.2	15.7	13	31.2	1.1	14.3	1.0	8.4	936	-0.2
Hammermill Paper	787	14.1	11.1	20	-2.2	1.6	6.7	0.2	8.2	140	NA
Kimberly-Clark	1725	8.8	9.0	131	14.9	23.1	6.0	1.3	17.7	809	0.6
St. Regis Paper	1996	11.0	11.0	107	7.5	8.4	11.6	0.4	7.9	272	-1.4
Scott Paper	1520	10.7	12.7	62	2.4	25.9	6.2	1.7	41.7	1217	1.1
Sorg Paper	54	1.1	6.4	0	NA	0.6	11.8	1.1	253.0	972	-1.0
Westvaco	1001	8.5	9.6	62	6.2	8.5	-0.4	0.8	13.7	534	-1.4
Industry composite	10835	9.9	10.8	565	6.2	94.5	8.2	0.9	16.7	562	-0.5
PERSONAL & HOME CARE PRODUCTS											
Alberto-Culver	150	4.1	-1.3	2	-11.3	1.2	6.2	0.8	52.9	598	
Avon Products	1648	14.9	8.9	192	11.7	15.8	16.5	1.0	8.2	577	
Block Drug	127	6.3	9.2	12	8.9	2.2	18.0	1.7	18.3	1228	
Bristol-Myers	2191	10.3	12.4	174	14.3	80.7	16.9	3.7	46.3	2602	
Carter-Wallace	161	-1.9	0.8	5	-28.1	9.2	1.4	5.7	196.0	3062	
Chesebrough-Pond's	808	8.2	14.4	60	11.6	7.1	13.5	0.9	11.8	427	
Clorox	873	6.2	21.7	32	7.6	6.6	26.6	0.8	20.3	1093	
Colgate-Palmolive	3837	9.3	11.0	161	13.6	33.6	6.7	0.9	20.9	634	

R&D SPENDING: 1977

COMPANY	SALES: 1977 MILLIONS OF DOLLARS	SALES: PERCENT CHANGE FROM 1976	SALES: PERCENT AVERAGE ANNUAL CHANGE	PROFITS: 1977 MILLIONS OF DOLLARS	PROFITS: PERCENT AVERAGE ANNUAL CHANGE	RESEARCH & DEVELOPMENT EXPENSE: 1977 MILLIONS OF DOLLARS	R&D: PERCENT CHANGE FROM 1976	R&D: PERCENT OF SALES	R&D: PERCENT OF PROFITS	R&D: DOLLARS PER EMPLOYEE	EMPLOYMENT: PERCENT AVERAGE ANNUAL CHANGE
Culligan International	93	12.7	9.3	4	1.2	1.3	16.6	1.4	32.9	594	-0.5
Gillette	1587	6.4	10.3	80	-3.5	38.2	9.4	2.4	47.9	1205	3.0
Helene Curtis Industries	119	12.1	14.6	3	32.2	1.6	25.3	1.3	60.6	925	NA
Johnson Products	33	-17.0	9.1	1	-18.9	0.7	40.8	2.2	52.7	1572	13.3
La Maur	29	7.2	5.0	1	14.1	0.5	18.7	1.6	60.2	1187	-1.1
Noxell	138	12.7	10.6	9	10.3	1.7	29.0	1.2	17.9	1560	4.1
Procter & Gamble	7284	11.8	16.5	461	11.4	165.3	13.7	2.1	33.7	2876	NA
Purex	491	5.5	6.4	22	7.7	1.9	5.8	0.4	8.9	278	-3.7
Revlon	1143	19.6	21.6	98	20.8	20.7	30.6	1.8	21.1	795	11.6
	20713	10.2	12.9	1317	10.2						3.8

SEMICONDUCTORS

COMPANY	SALES: 1977 MILLIONS OF DOLLARS	SALES: PERCENT CHANGE FROM 1976	SALES: PERCENT AVERAGE ANNUAL CHANGE	PROFITS: 1977 MILLIONS OF DOLLARS	PROFITS: PERCENT AVERAGE ANNUAL CHANGE	R&D: 1977 MILLIONS OF DOLLARS	R&D: PERCENT CHANGE FROM 1976	R&D: PERCENT OF SALES	R&D: PERCENT OF PROFITS	R&D: DOLLARS PER EMPLOYEE	EMPLOYMENT: PERCENT AVERAGE ANNUAL CHANGE
Advanced Micro Devices	62	80.6	44.6	4	35.7	5.5	159.3	8.9	123.6	1876	40.9
American Microsystems	71	5.9	3.0	2	NA	6.7	3.5	9.4	381.2	2257	2.3
Fairchild Camera & Instrument	460	3.8	7.1	11	-22.0	43.6	1.4	9.5	390.6	2192	-0.9
General Instrument	466	24.0	8.4	17	7.7	17.5	10.1	3.7	105.6	704	NA
International Rectifier	85	44.4	8.4	1	-24.2	1.4	4.9	1.7	195.4	557	-3.9
Intersil	82	13.4	10.1	4	NA	6.6	-3.0	8.0	153.1	2990	NA
Mostek	86	48.5	14.9	6	-3.6	4.8	22.5	5.6	83.9	1219	39.2
Motorola	1848	20.4	9.9	106	5.7	109.7	13.8	5.9	103.3	1829	6.9
National Semiconductor	387	19.1	37.0	10	24.1	31.8	28.1	8.2	312.6	1470	28.2
Texas Instruments	2046	23.4	10.3	117	7.9	96.2	33.6	4.7	82.4	1403	1.5
Industry composite	5593	20.9	11.0	278	4.2	323.8	22.1	5.8	116.6	1546	14.7

SERVICES: Engineering, data service, leasing

COMPANY	SALES: 1977 MILLIONS OF DOLLARS	SALES: PERCENT CHANGE FROM 1976	SALES: PERCENT AVERAGE ANNUAL CHANGE	PROFITS: 1977 MILLIONS OF DOLLARS	PROFITS: PERCENT AVERAGE ANNUAL CHANGE	R&D: 1977 MILLIONS OF DOLLARS	R&D: PERCENT CHANGE FROM 1976	R&D: PERCENT OF SALES	R&D: PERCENT OF PROFITS	R&D: DOLLARS PER EMPLOYEE	EMPLOYMENT: PERCENT AVERAGE ANNUAL CHANGE
American District Telegraph	254	11.2	12.3	17	9.5	4.0	7.1	1.6	23.9	481	1.9
AMFAC	1322	13.2	11.2	34	-6.3	2.0	39.4	0.2	6.0	85	NA
Automatic Data Processing	245	23.2	24.4	23	25.9	6.9	24.9	2.8	29.5	880	NA
Computer Sciences	235	6.7	19.0	12	117.2	3.0	-1.0	1.3	25.8	411	NA
Damon	130	1.0	2.0	1	-44.5	2.1	4.0	1.6	161.7	458	NA
Engelhard Min. & Chem.	7333	13.4	21.4	123	20.0	7.2	12.5	0.1	5.9	NA	NA
Foremost-McKesson	2695	5.6	7.8	36	3.9	2.0	14.3	0.1	5.6	120	-1.5
Kaman	214	16.2	11.6	5	14.0	1.4	54.0	0.7	25.9	421	0.4
National CSS	42	17.1	25.1	3	33.7	2.5	6.9	6.0	77.9	3890	NA
Nolex	43	11.2	NA	0	NA	1.1	204.8	2.5	618.2	4405	NA
Pittway	257	56.0	26.6	30	36.3	1.6	19.6	0.6	5.3	411	14.5
Pullman	2020	-2.9	19.6	33	-4.3	8.4	7.7	0.4	25.4	261	6.8
Tetra Tech	25	34.5	45.3	1	56.3	1.0	51.2	4.0	77.8	1825	NA
Tymshare	101	23.6	26.1	8	37.3	4.3	-19.1	4.2	53.1	1850	NA
Univar	666	18.8	21.0	-1	NA	1.4	9.1	0.2	-156.4	341	2.0
Industry composite	15584	10.5	14.5	324	18.4	48.7	15.9	0.3	15.0	421	2.4

STEEL

COMPANY	SALES: 1977 MILLIONS OF DOLLARS	SALES: PERCENT CHANGE FROM 1976	SALES: PERCENT AVERAGE ANNUAL CHANGE	PROFITS: 1977 MILLIONS OF DOLLARS	PROFITS: PERCENT AVERAGE ANNUAL CHANGE	R&D: 1977 MILLIONS OF DOLLARS	R&D: PERCENT CHANGE FROM 1976	R&D: PERCENT OF SALES	R&D: PERCENT OF PROFITS	R&D: DOLLARS PER EMPLOYEE	EMPLOYMENT: PERCENT AVERAGE ANNUAL CHANGE
Allegheny Ludlum Industries	1002	12.7	7.8	25	-9.0	10.7	16.9	1.1	42.1	424	NA
Athlone Industries	235	3.0	3.1	10	4.1	3.0	9.5	1.3	30.3	845	-5.0
Bethlehem Steel	5370	2.3	5.1	-448	NA	42.7	-2.3	0.8	-9.5	427	-2.4
Bundy	113	6.9	7.6	8	11.4	1.6	26.1	1.4	20.1	621	-3.3
Carpenter Technology	326	22.5	9.6	29	15.4	9.2	22.0	2.8	32.2	1979	-0.6
Lykes	1767	8.7	5.9	-190	NA	3.5	-18.5	0.2	-1.8	124	[illegible]
Republic Steel	2909	14.3	6.3	41	[illegible]	16.8	3.2	0.6	40.9	410	[illegible]
U.S. Steel	9610	11.2	5.9	138	-18.7	49.8	-4.6	0.5	36.1	300	[illegible]
Industry composite	21331	9.1	5.9	-387	-15.6	137.4	0.1	0.6	-35.5	370	[illegible]

R&D SPENDING: 1977

COMPANY	SALES: 1977 MILLIONS OF DOLLARS	SALES: PERCENT CHANGE FROM 1976	SALES: PERCENT AVERAGE ANNUAL CHANGE	PROFITS: 1977 MILLIONS OF DOLLARS	PROFITS: PERCENT AVERAGE ANNUAL CHANGE	RESEARCH & DEVELOPMENT EXPENSE: 1977 MILLIONS OF DOLLARS	R&D: PERCENT CHANGE FROM 1976	R&D: PERCENT OF SALES	R&D: PERCENT OF PROFITS	R&D: DOLLARS PER EMPLOYEE	EMPLOYMENT: PERCENT AVERAGE ANNUAL CHANGE
TELECOMMUNICATIONS											
AT&T	36495	-11.2	11.7	4544	11.1	717.7	11.5	2.0	15.8	935	-0.7
Communications Satellite	168	9.5	8.6	31	-4.6	7.5	-1.4	4.5	24.2	5489	4.0
GTE	7680	13.8	10.6	560	10.4	112.0	5.7	1.5	20.0	552	NA
United Telecommunications	1191	18.5	12.5	137	16.2	14.4	10.1	1.2	10.5	587	-2.1
Western Union	650	7.1	7.0	45	10.5	4.8	-26.4	0.7	10.7	342	-4.5
Industry composite	46185	11.7	11.4	5317	11.0	856.5	10.3	1.9	16.1	848	-0.8
TEXTILES, APPAREL											
Albany International	258	8.3	9.7	16	2.2	5.7	13.8	2.2	35.0	911	0.8
American Mfg.	36	21.0	8.7	13	6.3	0.5	30.4	1.5	4.3	524	0.5
Burlington Industries	2388	4.5	2.4	90	4.8	5.0	0.0	0.2	5.6	73	-5.0
Collins & Aikman	466	13.5	10.0	19	8.5	3.3	0.0	0.7	17.0	310	NA
Fieldcrest Mills	417	20.8	9.0	17	40.7	4.9	-1.8	1.2	28.3	394	-0.5
Huyck	108	5.6	13.7	7	-1.2	4.2	12.7	3.9	58.6	1306	NA
Martin Processing	122	4.4	9.9	6	-0.9	1.0	-36.2	0.8	15.2	656	[illegible]
Reeves Brothers	272	14.2	8.2	10	7.0	1.4	5.2	0.5	13.1	160	2.2
J. P. Stevens	1539	8.3	7.9	35	3.1	3.2	4.5	0.2	9.2	734	0.2
Industry composite	5607	8.1	5.8	215	5.4	29.2	1.3	0.5	13.6	186	-1.2
TIRES & RUBBER											
Amerace	280	11.9	5.8	10	-1.4	6.8	22.0	2.4	70.0	1006	-2.0
Armstrong Rubber	367	11.6	12.2	15	28.2	4.9	4.7	1.3	32.6	860	NA
Bandag	200	9.8	16.0	18	10.1	1.6	4.1	0.7	8.2	693	6.1
Cooper Tire & Rubber	247	2.7	14.6	8	21.0	3.3	13.8	1.3	43.1	817	3.2
Firestone Tire & Rubber	4427	12.4	7.8	110	-12.0	60.3	12.8	1.4	54.7	524	0.2
General Tire & Rubber	2110	4.3	10.6	116	11.6	17.5	5.0	0.8	15.1	438	1.1
B. F. Goodrich	2223	11.3	6.2	60	-12.9	44.8	6.8	2.0	74.5	1132	-6.1
Goodyear Tire & Rubber	6628	14.4	8.3	206	1.6	121.5	7.0	1.8	59.1	795	0.5
Mansfield Tire & Rubber	112	-8.7	4.3	-5	NA	1.4	10.9	1.3	-29.0	1028	-9.7
Mohawk Rubber	202	11.6	15.0	4	20.5	1.7	9.9	0.8	39.8	550	NA
Uniroyal	2582	11.5	4.4	35	-13.0	66.0	11.9	2.6	189.7	1235	[illegible]
Industry composite	19378	11.5	7.8	577	0.4	329.7	9.2	1.7	57.1	778	-0.8
TOBACCO											
American Brands	2892	11.9	9.9	158	4.8	15.1	-1.0	0.5	9.5	279	NA
Liggett Group	817	3.3	6.7	3	-37.8	4.1	5.1	0.5	157.5	482	NA
Industry composite	3709	10.3	9.3	160	1.1	19.2	0.8	0.5	11.9	306	NA
All-industry composite	971562	11.5	12.6	52132	9.6	18047.6	16.4	1.9	34.6	1240	[illegible]

TECHNOLOGY TRANSFER

A Review of the Economic Issues

U.S. International Trade Commission
U.S. Department of Commerce
U.S. Department of Labor

A Study
Pursuant to Section 119 of the
Export Administration Amendments of 1977
[Public Law No. 95-52]

Washington, D.C.
June 1978

28-558 O - 78 - 21

EXECUTIVE SUMMARY

The U.S. International Trade Commission, the U.S. Department of Commerce, and the U.S. Department of Labor collaborated to study the economic effects related to United States transfers of technology abroad. This study was mandated by Section 119 of the Export Administration Amendments of 1977 (Public Law 95-52, approved June 22, 1977). The results of the study are contained in this report. The report outlines the economic issues related to studies of technology transfers and their impacts.

Although not enough evidence was found to estimate the impact of technology transfers on U.S. trade, production and employment, several important conclusions were reached:

* There is evidence that the United States is losing its competitive position (as measured by market shares) in international markets for several products that have been characterized as technologically intensive.

* There is some evidence that high technology content is important to the competitiveness of products in international markets, but the evidence is not overwhelming.

* There is no conclusive evidence that U.S. exports of technology are hurting or helping the competitive position or the overall economic position of the United States. However, certain domestic employees and firms, and their communities may experience dislocation costs when technology is transferred abroad.

* It is very difficult to estimate the economic impacts of U.S. technology transfers on the U.S. economy.

    - There is considerable ambiguity as to the meanings of the concepts of technology, technological change and technology transfer.

    - No good measurements of technology, technological change and technology transfer now exist. Their absence, especially for technology transfers, presents a very great hindrance to the analysis of transfer effects.

    - Relevant data on the prices and quantities of products and factors of production do not exist in sufficiently disaggregated form, or where they do exist, their availability is limited. These data could aid in obtaining better estimates of the impact of technology transfers.

- In any estimate of the impact of technology transfer, the problem always exists of hypothesizing what would have happened had the technology transfer not occurred.

* The most common measurements used to judge the technological levels of industries are of questionable value. The necessary use of proxies as indicators of the technological level of an industry results in only the broadest characterizations, limiting the significance of inter-industry comparisons. Inter-country comparisons of industries generally are not available owing to a lack of comparable data from other countries.

* There are many channels for technology transfers abroad, such as through product exports, licensing, scientific publications, and international meetings. Direct investment abroad is one of the most important channels for U.S. technology transfers. Therefore, tax and other regulations on foreign investment are especially important to technology transfer.

* Government policies in the technology-exporting and technology-importing countries affect the total amount of technology transfers and the methods by which these transfers are made. For example, higher taxes or more strict regulations that slow transfers through one channel of technology transfer may result in increased transfers through other channels.

* There are severe shortcomings in our current measures of technology transfer. Areas in which improvements might be made are indicated below. This list is only suggestive and should be considered by the Subcommittee on Technology Transfer of the Interagency Committee on International Investment Statistics.

  - Data collection on current sales and purchase of technology. Present fee and royalty data are for receipts and payments for the stock of all past technology transfers, and hence do not tell us the relative size of current technology inflows and outflows.

  - Data collection on products involved and the quantity of foreign production when technology is licensed to a non-affiliated foreign recipient. These data would be necessary in order to relate transfers of technology to non-affiliated foreigners with the possible impact on U.S. trade.

- Data collection on transfers of proprietary technology not paid for by fees or royalties. Examples of such transfers would include technology sold in exchange for equity in the receiving firms, technology traded in exchange for other technology, technology transferred to affiliates with no explicit fee or royalty charges and "turnkey" operations.

- Collection of a set of qualitative as opposed to quantitative data on technology transfers. A special survey would be needed. Merchandise exports could be classified as being new products in the recipient country, or as having competition in the recipient country and, if so, whether the substitutes are imported from third countries or produced domestically. Additional data might include questions on whether or not the process involved in the technology transfer is already present in the recipient country or if other foreign sources are available. Data might be collected on the number of transactions, the host country for each transaction and the channel (for example, licensing to a non-affiliated foreigner, or direct foreign investment) used to accomplish the transfer. Some description of the technology, including information on how long it has been available in the United States and how it might differ from similar technology available abroad would also be useful.

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THE ECONOMICS OF INTERNATIONAL TECHNOLOGY TRANSFER

I. INTRODUCTION TO THE ANALYSIS

A. Legislation

This study has been prepared in response to legislation enacted in June 1977 charging the U.S. Department of Commerce, the U.S. Department of Labor and the U.S. International Trade Commission to examine the domestic economic impacts of the export of advanced industrial technology from the United States. The mandate, contained in section 119 of the Export Administration Amendments of 1977 (Public Law 95-52), states:

> (a) The President, acting through the Secretary of Commerce, the Secretary of Labor, and the International Trade Commission, shall conduct a study of the domestic economic impact of exports from the United States of industrial technology whose export requires a license under the Export Administration Act of 1969. Such a study shall include an evaluation of current exporting patterns on the international competitive position of the United States in advanced industrial technology fields and an evaluation of the present and future effect of these exports on domestic employment.
>
> (b) The results of the study conducted pursuant to subsection (a) will be reported to the Congress within one year after the date of enactment of this Act.

For the purposes of this study, it has been necessary to ascertain the scope and types of technology to be examined. The legislation states that inquiry is to be focused upon that industrial technology which requires an export license under the Export Administration Act of 1969. 1/ Under regulations promulgated pursuant to the 1969 act, 2/ there are two types of export licenses administered by the Office of Export Administration, in the U.S. Department of Commerce. The first type is the "general license," 3/ a license which provides blanket approval for the export of certain types of technical data that are "generally available," as well as "scientific or additional data." 4/ The general license applies to the bulk of technology and technological data which moves in international trade. The second type of license, a "validated license," is required for all other types of technical data, including generally higher level technology and technological data which are not covered by the requirements for general licenses. 5/ A request for a validated license must be submitted to the Department of Commerce for approval on a case-by-case basis in order that control of exports, as necessary to the national security of the United States, is exercised. The controls are invoked most frequently when the license involves shipment of higher level technology to the Communist countries. The language of section 119 has been interpreted to include examination of transfers of technology in the broad sense, namely, examination of those transfers covered

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1/ Public Law No. 91-184, approved Dec. 30, 1969, 83 Stat. 841, 50 U.S.C. App. 2401 et seq. (1969).
2/ 15 CFR. 379 (1977).
3/ 15 CFR. 379.2 (1977).
4/ 15. CFR. 379.3 (1977).
5/ Certain exports to Canada are excepted. 15 CFR. 379.5 (1977).

by both general and validated licenses, and the effect of those transfers upon the international competitive position of U.S. advanced technology fields and upon domestic employment. To have focused only on technology transfers requiring a validated license would have had the effect, in large part, of limiting the study to issues of West-East technology transfer.

The legislation addresses a recognized need for an overview of the main issues associated with technology transfers and a perspective on the extent of their impacts. The basic concern is to know whether, to what extent, and how technology transfer harms or benefits the economy of the United States. Such information presumably would indicate to the Congress and other policymakers the relative feasibility and desirability of adopting measures that might either accelerate or inhibit technology transfer in accordance with the national economic interest.

B. The Perception of Technology Transfers as a Problem

The mandate from the Congress conveys a growing concern about the possible adverse economic effects of technology transfer. This concern stems, in part, from analyses of eminent economists 1/ and from statistical evidence that indicates that the U.S. has been losing its competitive edge in markets for certain high-technology-content products in which the United States previously held a strong leadership position. Some evidence of this slippage was recently presented by Aho and Carney 2/ in a report which was used as the basis for testimony before the Senate Subcommittee on International Finance. Figure 1 shows the results of comparing the U.S. share of Organization for Economic Cooperation and Development (OECD) exports of technology-intensive manufactured products 3/ with the market shares of Germany, Japan, and the United Kingdom. The Aho and Carney analysis supports the argument that a significant part of the decline in the relative trade performance of the United States in the past several years has been caused by structural changes in the U.S. economy that have adversely affected the U.S. comparative trade advantage. Another view is that price effects (e.g., overvalued dollar) and

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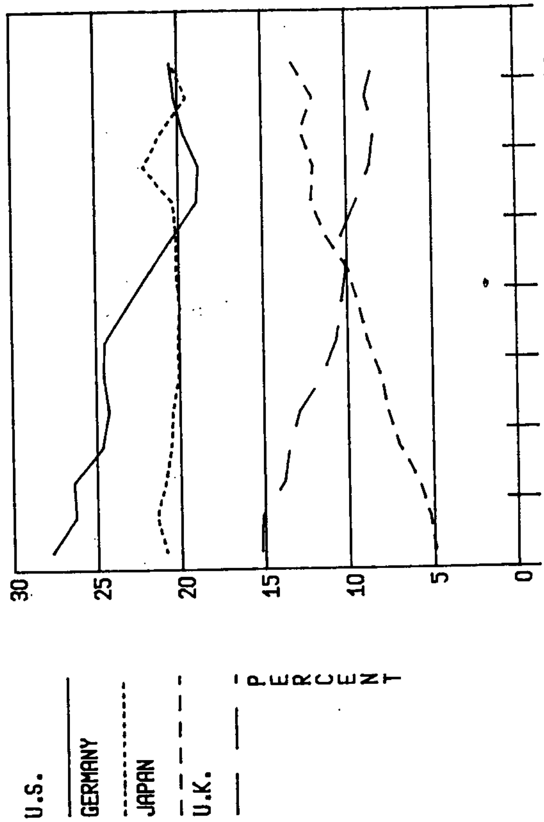
1/ Harry Johnson, "Technological Change and Comparative Advantage: An Advanced Country's Viewpoint," Journal of World Trade Law, January-February 1975, pp. 1-14. Johnson notes that patterns of comparative advantage were considered in the past to be fixed by nature, or subject to slow, regular and predictable change. He says that it is now clear that technological change and its diffusion in response to differences in labour costs is a chronic disturber of existing patterns of comparative advantage. Johnson points out how these disturbances impose an adjustment burden on individual workers and their communities.

2/ C. Michael Aho and Richard D. Carney, "United States Export Performance in the Post-Devaluation Period: Continuation of a Secular Decline?" Report submitted to the Subcommittee on International Finance of the Committee on Banking, Housing and Urban Affairs of the United States Senate, Washington, D.C., Feb. 23, 1978.

3/ Technology-intensive products include chemicals, nonelectrical machinery, electrical machinery, transport equipment, scientific instruments and miscellaneous manufactures according to the Standard International Trade Classification (SITC). They exclude the metallurgical industries, textiles, footwear, and the like.

FIGURE 1

INDIVIDUAL COUNTRY SHARES
OF TOTAL OECD EXPORTS
OF HIGH TECHNOLOGY PRODUCTS
(SITC NUMBERS 5,7,86,89)



SOURCE: C. Michael Aho, Testimony before the Senate Sub-Committee on International Finance, 23 Feb. 1978.
OECD TRADE SERIES C

cyclical changes (e.g., slow European and Japanese growth) have been responsible for recent U.S. trade problems. Casual evidence for the Aho and Carney argument is the observation (see figure 1) that Germany and Japan have been able to maintain and increase their market shares despite the appreciation of their currencies and the resulting favorable price movement for U.S. exports.

While arguing that non-price factors are an important cause of the adverse U.S. trade position, Aho and Carney state that they could not identify the specific factors contributing to the observed changes in the pattern of U.S. exports. 1/ A prominent group of observers, however, has charged that U.S. technology transferred abroad through capital exports and licensing arrangements has been a major cause of adverse effects on the economy. 2/ Advocates of this adverse impact theory argue that the massive foreign direct investment and licensing activities of U.S.-based multinational corporations during the 1950's and 1960's exported jobs along with technology. They contend that the United States is continuing to lose production and employment through its diminishing share of the world market because of continued technology transfers. Technology transfer is said to be responsible for the fact that employment in manufacturing has not recovered to its 1969 level in the U.S. in spite of a substantial growth in the private sector as a whole. 3/

Such arguments identify technology transfer as a significant causal element of the loss of related U.S. market share, whereas many other factors influence comparative advantage in trade. The effects of decreased growth in domestic research and development efforts, lower productivity growth, increased research and development abroad, accessibility to markets, national business attitudes, and a host of other considerations also influence the U.S. comparative advantage in trade.

C. The Research Implications of Section 119

It is implicit in the Congressional mandate that all of the above considerations impinging on economic growth and trade patterns can be separated from the impact of technological transfer. It is further implicit that the technology component of foreign trade, investment, and other transfer mechanisms can somehow be identified and isolated. This component must then be measured and related back to the domestic economy in order that conclusions can be reached about the net impact on the U.S. economy. These are not easy tasks. Furthermore, these questions presume a knowledge of what would have occurred in the absence of U.S. technology transfers.

1/ Aho and Carney, op. cit. p. 29.
2/ For an example, see the statement of Jacob Clayman of the AFL-CIO before the Senate Subcommittee on Multinational Corporations, Washington, D.C., Dec. 10, 1975.
3/ However, manufacturing employment in the seventies has also declined (and to a greater extent than in the United States) in Germany, the Netherlands, the United Kingdom, and Japan. See International Economic Indicators, U.S. Department of Commerce, Dec. 1977, p.82.

Given the time and resource limitations and the substantial gaps in current knowledge of the technology transfer process and of its repercussions, the tri-agency staff was not able to execute a quantitative analysis of the economic consequences of technology transfer. No conclusions were reached by the staff as to whether the ultimate effects of U.S. technology transfer are beneficial or detrimental to U.S. economic well-being. Instead, the staff conducted an extensive review of the state-of-the-art of technology transfer theory. The review covered relevant economic theory, methodology, and data.

To arrive at any supportable conclusions on the broad issues raised by the mandate will probably be very difficult. The linkage between technology transfer (itself an unclear concept) and the economic consequences of the transfer are very tenuous. Many theoretical issues remain unresolved, and there seems to be no clear methodological approach to their resolution. Most of the important key data remain uncollected and may prove very difficult to collect.

In this report the tri-agency group has attempted to outline the basic issues and the methodological problems that have made it infeasible to answer questions about the effects of technology transfers. It draws on economic concepts and terminologies. These ideas and vocabularies have been simplified whenever possible. As its primary goal the report attempts to conceptualize the theories involved and to explain the analytical pitfalls that have prevented previous investigators from reaching conclusive statements about technology transfer. We hope that this report will stimulate innovative research on this topic in the future.

D. Guide to the Chapters

Chapter II, "Technology Transfer--Theory, Methodology, and Data," begins with a presentation of the economic concepts of technology and technology change. From this point the paper proceeds to discuss approaches used to identify advanced industrial technology fields. Next, the discussion outlines the problems of defining what is meant by technology transfer, identifying transfer processes, and measuring the transfers. Although other serious problems exist in any attempt to establish a causative linkage between technology transfer and subsequent economic impacts, the difficulties surrounding the identification and measurement of the transfers themselves present the most immediate obstacle. The final sections of the chapter address the economic impact to be expected from technology transfers. The major measurement problems to be confronted in this area are as follows: (1) The impacts of technology transfer are complex, involving product, labor, and capital markets both abroad and at home; (2) much of the data required have not been collected; (3) segregating the impact of technology transfer from the impact of other economic forces is difficult; (4) the problem remains of judging what would have occurred had U.S. technology not been transferred.

Chapter III, "The Trade Competitiveness of High-Technology Industries," examines comparative trade advantages of high-technology industries. The concept of competitiveness is discussed first. Next, several studies that have examined the link between technology and trade flows are reviewed. Finally, U.S. trade patterns in R&D intensive industries are presented. Chapter IV closes with conclusions and implications for future research.

II. TECHNOLOGY AND TECHNOLOGY TRANSFER--THEORY, METHODOLOGY, AND DATA

A. Introduction

The relationship between transfers of U.S. technology abroad and U.S. trade, production, and employment has become an increasingly significant topic in recent years, particularly to those policymakers in the United States who have viewed with alarm the rise in U.S. imports of technologically sophisticated products and the increasing competition in foreign markets for U.S. exports of these products. At issue is whether the relatively unimpeded flow of "advanced" U.S. technology abroad is injuring the U.S. economy. "Injury to the U.S. economy" is a concept that means different things to different people. Here, a broad view is taken, with "injury" implying that the impact of technology flows is to reduce real GNP or total employment. 1/ The pattern and timing of the impacts of technology transfers are also of interest. Which industries are most affected by these transfers? What are the timing and the extent of the effects? For example, a particular technology transfer may have a net beneficial impact on the U.S. economy in the long run, but may cause substantial adjustment costs to a particular industry in the short run. Hence both the net impacts and their pattern and timing are of potential interest to policymakers. Technology transfer can benefit as well as injure the U.S. economy. Presumably, the benefits and costs of technology transfer should be measured in terms of the alternatives, namely, what would have occurred in the absence of the transfer. In this section some of the more crucial assumptions needed for such an analysis are discussed.

Trade Theory.--The theory of international trade has developed gradually during the last half century. The most prominent trade theory bases the analysis of trade flows on the relative factor endowments of capital and labor among countries. Thus, countries with a relative abundance of labor would generally be expected to export labor-intensive goods and import capital-intensive goods. This classical theory of comparative advantage was seriously challenged by the results of research done by Leontief. 2/ The Leontief paradox indicated that U.S. imports were less labor intensive than U.S. exports, a result contrary to expectations. Many explanations for this paradox have been advanced and empirically tested.

1/ A normative judgment is not to be inferred from this definition. The first step is to determine the impact of the technology transfer flows.

2/ Wassily Leontief, "Domestic Production and Foreign Trade; the American Capital Position Re-examined," Economia Internazionale, vol. VII, No. 1, February 1954, pp. 3-32.

Attention was paid to other theories which would also explain trade. One such theory relevant to the technology transfer issue contends that technological differences among countries are reflected in products traded among them. Thus, high-technology countries such as the United States would tend to export goods incorporating relatively new and advanced technology and to import products utilizing standard or well-known technologies. Vernon's product cycle theory 1/ makes use of the concept of technology gap in explaining trading patterns over time. Products go through a life of their own in different stages--new, then maturing (when technology spreads to industrialized countries other than the originator), and finally standardized. Following this line of reasoning, a high-technology country such as the United States should have a comparative advantage in new products; and the longer the product stays in the new stage, the longer it should maintain its high level of export competitiveness. If this hypothesis is valid, then the greater the export of technology, the smaller the technology gap and thus the sooner the comparative advantage diminishes for the home country's exports. 2/ The product cycle theory directly relates a country's comparative advantage to its relative technological expertise as embodied in its traded goods.

Should the product cycle theory have explanatory value, then one might be able empirically to determine the impact of technology transfers abroad on the volume and composition of trade and consequently on the domestic economy in terms of production and employment effects. 3/ Unfortunately, a series of problems makes the undertaking of such an analysis extremely difficult. The remainder of this section is concerned about these problems and what approaches might be taken to resolve them.

Definitional Problems in Measuring Change in Technology.--Many different concepts fall under the umbrella of 'technology transfer.' Analytically, there are two separate definitional problems concerning technology to be discussed in this paper: (1) What constitutes technology? and (2) What does it mean to say that technology has been transferred from one country to another? One definition of technology is:

> Technology is knowledge or information that permits some task to be accomplished, some service rendered, or some product produced. Conceptually, technology can be distinguished from science, which organizes and explains data and observations by means of theoretical relationships. Technology translates scientific relationships into "practical" use. 4/

1/ Raymond Vernon, "International Investment and International Trade in the Product Cycle," Quarterly Journal of Economics, May 1966, pp. 190-207.

2/ This statement assumes that other factors which affect the technology gap and comparative advantage remain constant.

3/ Economic research indicates that the product cycle theory, to some extent explains trade patterns.

4/ G. R. Hall and R. E. Johnson, "Transfers of United States Aerospace Technology to Japan," The Technology Factor in International Trade, edited by Raymond Vernon, National Bureau of Economic Research, New York 1970, p. 306 (footnote 2).

Admittedly, this definition of technology is very broad and does not provide much guidance as to how technology might be measured. Rather than measure the total level of technology embodied in some process or "possessed" by some country, it may be more convenient to look at changes in the level of technology.

Mansfield has examined the broader question of technological change, the process by which more output is produced from the same amount of input or less inputs are required for the same amount of output. He defines technological change as:

> the advance of technology, such advance often taking the form of new methods of producing existing products, new designs which enable the production of products and important new characteristics, and new techniques of organization, marketing and management. 1/

Such a definition of technological change that is associated with changes in factor productivity probably is too restrictive in a world in which new products are being introduced and tastes are changing over time, often in response to the availability of new products. Technological change associated with new or improved products should be considered as well, but the relationship between new or modified products and technological change needs to be defined carefully. 2/ Although much of the empirical literature appears to treat all product changes as technological changes, there is some question as to whether this is the proper procedure.

For products whose output can be measured empirically, an assessment of technological change is feasible. For example, a new calculator which performs an operation more quickly than a previous model at the same factor costs could be said to embody a technological change. The problem, however, becomes more complicated if the "new" product is used in the form of direct consumption, thus providing psychic pleasure but not enabling someone to be able to accomplish something which could not be done previously. Presumably, for these products one should relate their technological component to whether their purchases cause total satisfaction to increase. One approach to determining this might be to compare the value of the new product with the old one given the same amount of factor inputs--i.e. whether the price of the new item is higher using the same factor inputs for comparison (this approach assumes the factor inputs themselves have not been affected by technological change). Another approach would be to take equal values of the two products and compare the values of the factor inputs used in each. However, all product changes may not represent technological advances. Suppose a calculator is introduced having a new design (e.g., rounded keys instead of square keys) but costs the same to produce and sells for the same price as calculators with the old design. This change could be said to represent product differentiation rather than technological change.

1/ Edwin Mansfield, <u>The Economics of Technological Change</u>, New York, 1968, pp. 10-11.

2/ It is important to remember the distinction between product and process. A new process implies a changed technological relationship among inputs used to produce an output. Process innovations have been much more intensively researched than product innovations.

The purpose of this discussion is to give an idea of the conceptual problems involved in identifying what constitutes a technological change. One of the principal problems appears to be the need to distinguish newness of a product from technological change--i.e., one should not automatically identify a new or modified product as involving technological change. Certainly, there is no standard definition in use in the empirical work which has been attempted in this field. As a consequence of having this definitional problem, there is a serious measurement problem.

Comparative Measures of Technology Intensity.--Even if one could measure technological change or the degree of use of technology for a product or process, individual measurements would have to be aggregated in some way so as to characterize industries according to their relative applications of technology. Most research that has been done in the area of technology transfer has been done on a case-study basis. This approach is used because of the complexities involved in particular transfers. However, generalizations about technology transfers and about their relationships to trade necessitate the aggregation of measurements of technology transfer to broad industry-group or product-group levels. Because of the deficiency of detailed measurements that could be aggregated, researchers have used proxy measures to characterize the degree of technological achievement in an industry.

Identification of Advanced-Technology Fields.--The conventional approach is to use expenditures for research and development (R&D) as a proxy for areas which are characterized as having a fairly high level of technological sophistication. Alternatives to the R&D method exist, and that which appears to be most promising is the innovative process (IP) method. Both methods are presented and compared here to indicate their respective strengths and weaknesses. It is possible that the two approaches together may serve as a more precise method of depicting high-technology sectors. Briefly, the R&D approach concerns itself with those states of technological progress preceding commercialization of the technology. In contrast, the IP approach looks at the broader aspects of technological progress, including commercialization of the technology parcel, but in doing so it deemphasizes the source of the basic technology.

Research and development activity can be characterized as basic research, applied research, and product development. Basic research is work undertaken for the advancement of scientific knowledge and discovery, which form a tiny but essential core of all technological progress. Applied research is an extension of basic research, with a specific practical aim in view. Product or process development draws on the findings obtained from basic and applied research to develop new materials, devices, products, processes, and systems, or to improve existing ones.

R&D indicators are frequently used as a means of classifying industries according to technological intensity. Some indicators are the number of scientific and technical workers in an industry (as a percentage of industry employment), number of patent applications, and R&D spending as a percentage of total sales. There is some question as to the comparability of this information across industry or product lines. For such comparisons one must assume that one scientist or technician, one patent application, or one dollar spent on R&D is equally "productive" in the technological sense in one industry or product line as in another. Furthermore, for such R&D indicators to be a good proxy for technology intensity, it is necessary to associate a concentration of R&D activities with the commercial performance of an industry or product line.

While many studies accept a high level of R&D expenditures as indicative of a high-technology industry sector, such a relationship should not be interpreted as a causative one. Although R&D activities serve to enlarge the technical capability needed to advance the state of technology in a firm's operations, additional inputs (e.g., managerial knowhow) are required to achieve technological progress. The role of research and development in the hierarchy of technological progress may be appreciated from a cost viewpoint. A 1967 Department of Commerce study concluded that, as a rule of thumb, for each dollar spent on basic R&D, 10 more are required for applied R&D and product development, and an additional 100 for commercialization of the technology package in the form of new or improved products or services. 1/

The IP method is concerned with the interplay of technical and managerial knowhow and the actual introduction into the marketplace of a new or improved product or service. The distinguishing characteristic of the IP concept is that it focuses attention on the incorporation of new technology into a firm's production function in order to generate new or improved output to meet market needs. To determine the usefulness of this approach for identifying advanced industrial technology sectors, a survey of innovative U.S. firms could be undertaken.

As in the R&D method, there are numerous indicators of the innovation process. Innovations generating improved products or processes can be classified in terms of their radicalness, the year of market introduction, the size of the innovating company and the industry to which it belongs, the R&D intensiveness of that industry, and the sources of technology underlying the innovation. Indicators of radicalness rely on qualitative judgment, and they can use a hierarchical classification such as the following: Radical breakthrough, major technical change, improvement to existing product, and imitation. The IP method, like the R&D method, encounters the problem of comparing the information provided by the indicators across industries or product fields. The principal difference between the IP method and the R&D approach is that the former uses outputs while the latter uses inputs to measure technological change. 2/

1/ Daniel V. DeSimone, Technological Innovation: Its Environment and Management, U.S. Department of Commerce, Jan. 1967. Furthermore, although economists would anticipate that the expected returns to additional, marginal increases in R&D expenditures should be in equilibrium across industries (and equal to the returns on additional expenditures on other factor inputs such as labor and capital), the average returns to R&D expenditures may differ markedly across industries. This apparent contradiction would occur if the marginal returns to R&D expenditures diminish at different rates in different industries.

2/ For a more complete description of the IP method of analyzing technological advance, see Gellman Research Associates, Indicators of International Trends in Technological Innovation, U.S. Department of Commerce, National Technical Information Service, PB-263 738, April 1976. (This report was prepared for the National Science Foundation, Washington, D.C.).

B. Technology Transfer

Concepts.--Technology may be transferred abroad in a variety of ways. For example, U.S. exports may have new technology embodied in them. To the extent that part of the payment received for these exports represents a payment for the technology, one can argue that a market value of that technology exists and is measureable. This is much more likely to be the case for arm's-length transactions than for intracompany transactions. However, even under ideal market circumstances, it may be very difficult to disentangle the technological component from the rest of the transaction. At best, one might hope to analyze "technologically embodied" transactions in terms of the overall impact on trade flows and on the exporting country's production and employment.

Another means by which technology can be transferred is through direct foreign investment. In this instance it has usually proven impossible to isolate the overseas profit component because of technology transfers incorporated in the processes or products involved in the investment. Direct foreign investments include joint ventures and mergers. Other examples of ways in which such transfers may be accomplished are foreign students, international conferences, scientific and professional publications, patent and other kinds of licensing, management and technical assistance contracts, and "turnkey" operations. Most concern over possible adverse impacts of technology transfer on the U.S. economy is expressed with regard to the transfer of proprietary technology by the private sector. For this reason, and also because it does not appear to be feasible to measure transfers of nonproprietary technology, this study focuses on transfers of proprietary technology.

Technology diffusion among countries can be viewed on two levels. On one hand, any transaction between two companies in different countries in which an exchange of technology occurs could be considered as a technology transfer. On the other hand, technology transfer could be seen in terms of transfers of technology that is new to the recipient country (i.e., a transfer of technology that does not already exist in the recipient country). From the point of view of economic theory, the latter represents technology transfer in that it results in a positive shift in the production possibilities curve 1/ of a country (i.e., the country's production potential increases), whereas the former may depict a firm moving from a less efficient to a more efficient production pattern using knowledge purchased abroad but which may have been

1/ The production possibilities curve represents the maximum combination of outputs that can be produced efficiently given all possible combinations of inputs. If a technology is available in a country, but it is not being utilized by some firm, then it may be that those firms are operating inefficiently. If there is domestic competition, they will be likely to be displaced by more technologically efficient firms. The acquisition from abroad of technology already available domestically does not affect the host country's production possibilities curve.

available domestically. 1/ This distinction is acknowledged in the field of research in determining which countries' industries have a comparative advantage owing to technological leadership. Using high R&D expenditures as a proxy for technological leadership implies an advantage due to differences in technology among countries.

Factors Affecting Technology Transfers.--The volume, method, and direction of technology transfers are based on the profit expectations of businesses regarding the alternative uses of the technology. These expectations are influenced by current and projected political and economic conditions as well as by previous experiences. The expected profits may be influenced, for example, by the monopolistic or competitive situation of the seller. In the latter situation, pressures may be greater for the transfer to occur to avoid loss of the sale or market to a competitor. Government policies may also affect the flows, particularly in the area of national security-related transfers. Exchange rate movements may result in changes in the flows of technology transfers, as these would affect actual and expected returns. For example, an exchange rate depreciation of the dollar vis-a-vis the German mark may lead to decisions against foreign investment (and thus production) in West Germany in favor of exports to West Germany by U.S. firms. Changes in costs may also affect technology transfers. An increase in shipping costs would tend to make merchandise exports less desirable relative to other technology transfer and foreign production.

An important consideration in the study of technology transfers is that the type of technology transferred, the vehicle through which the transfers take place, and the price paid for technology are often influenced by government policies. For example, according to Baranson, it is official policy in several Western European countries and Japan to encourage national firms to acquire advanced technologies in order to develop internationally

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1/ Under conventional assumptions of competition, the price of the technology should be the same whether purchased abroad or at home. Should the imported technology be less expensive, this fact would indicate some market imperfection. If the technology embodied in a piece of machinery cannot be duplicated domestically, the importation of additional units of the machine will increase the production possibilities of the recipient country because of the added capital but not because of the technology embodied in the machinery. The technology already exists within the country owing to the original importation of the machinery in question. The inability of the recipient country to reproduce the machinery indicates that the country lacks one or more factors of production necessary to build its own machine, but this inability does not signify that the technology embodied in the specific machinery in question does not exist within the recipient country.

competitive industries. 1/ Two examples of ways in which desired technology is attracted are (1) Tax incentives which attract direct foreign investment, and (2) trade barriers, which make the transfer of specific technologies more profitable. 2/ The extent to which such policies may be contributing factors of the technology transfer process cannot be ascertained.

Technology transfers to nonmarket economies are state-negotiated and hence strongly influenced by the policies of those countries, as well as by U.S. export restrictions on many technologies for reasons of national security. Since these countries' purchases are state-controlled, importer states may have some extra bargaining power where there are several competing suppliers of a given technology. Currently, transfers of technology to nonmarket economies are relatively small, and the policies of these countries prevent technology transfers through direct foreign investment, an important vehicle (note, however, that Yugoslavia, Romania, Hungary, and Poland allow minority ownership by Westerners in some industries).

The developing countries have asked for special treatment through international agreements so that they may obtain more cheaply the technology they need to aid in their development. Resource-rich developing countries usually have policies to encourage industrialization based on development of facilities to process and fabricate their raw materials for world markets. 3/ Many developing countries have begun to question the appropriateness of some of the advanced Western technology and to advocate the transfer of less capital-intensive technology. 4/

Measuring Technology Transfers.--Existing data on fees and royalties from abroad provide only a very crude indication of the amounts of technology being transferred. This statement is true for several reasons. First, since we do not know how to measure units of technology, we cannot be sure whether changes in the dollar amounts of receipts and payments of fees and royalties represent changes in the amount of technology being transferred, changes in the prices being paid for technology, or changes in both quantities and prices. For example, in an economic downturn, the prices paid in new technology transactions may fall along with the prices paid for many other production inputs. Besides general economic conditions, another factor that may influence the price of technology is a shift in the economic bargaining position between the seller (exporter) and buyer (importer) of technology. Presumably, if the latter were to become stronger, the prices paid for technology would tend to fall.

1/ Jack Baranson, "International Transfers of Industrial Technology by U.S. Firms and Their Implications for the U.S. Economy," paper prepared for the Bureau of International Labor Affairs, U.S. Department of Labor, December 1976, p. 11.

2/ Restricting imports encourages domestic production of the goods involved, and encourages owners of technology to produce behind the tariff walls rather than attempt to export over them to supply the protected market. For example, evidence that Canadian tariffs induce U.S. direct foreign investment in that country is given by Thomas Horst, "The Industrial Composition of U.S. Exports and Subsidiary Sales to the Canadian Market," The American Economic Review, March 1972, pp. 37-46.

3/ Jack Baranson, op cit. p. 14.

4/ For an analysis of this issue, see Ronald Findlay, "Some Aspects of Technology Transfer and Direct Foreign Investment," American Economic Review (Papers and Proceedings), May 1978, pp. 275-279.

Second, these data may not reflect accurately the value of private-sector technology transfers because they do not include all the payments made for these transfers and because they may reflect such things as tax considerations rather than just payment for technology. For example, some technology is sold in exchange for equity in the receiving enterprise, some technology is traded in exchange for other technology, and some multinationals transfer technology to their foreign affiliates without charging explicit fees or royalties. These factors would cause fees and royalties to understate the value of transfers of proprietary technology. On the other hand, fees and royalties include payments by subsidiaries for headquarters managerial staff, payments for film rentals, and payments for use of trademarks and copyrights. Also, multinationals may have an incentive to overcharge for fees and royalties in order to avoid foreign taxes on dividends. 1/

Finally, the existing data on U.S. payments and U.S. receipts of fees and royalties are not very useful in evaluating current trends in transfers of technology. This is true because receipts and payments are from the stock of past technology transfers and do not tell us the relative size of current technology inflows and outflows. For example, Japanese data show that Japanese receipts of fees and royalties were less than 15 percent of such payments by Japan in 1973. But data on sales and purchases of technology by Japan in 1973 showed that outflows slightly exceeded inflows in that year. Unfortunately, the U.S. Government currently does not collect information on technology sales or purchases. Thus, little is known about the relative magnitudes of current flows of technology to and from the United States. Data from an earlier OECD study indicated that during the 1960's, the United States was the major supplier of technology as measured by fees and royalties within the OECD. United States receipts for patents, licenses and royalties accounted for between 50 to 60 percent of total OECD receipts. 2/

A possible measure of technology transferred through direct foreign investment from parents to their foreign affiliates is research and development expenditures allocated to foreign operations as required by new tax regulations covering these expenses. This measure may be justified if the value of technology is closely related to the costs of developing it, 3/ and if the tax regulations result in the proper allocation of these costs to foreign income sources. However, little is known about the relationship between costs of development and the value of technology. 4/ In addition, the allocation of these costs to foreign profits is likely to be subject to large errors.

1/ See Jason Mirabito and Joseph M. Lightman, "Foreign Governmental Restrictions on Remittances From License Fees", The Outlook for U.S. Research and Development in Response to Changed IRS Tax Treatment, Foreign Business Practices Division, Office of International Finance and Investment, U.S. Department of Commerce, May 1977.

2/ OECD, Gaps in Technology, Paris 1970, p. 261.

3/ Research and development expenditures are commonly used in economic research as a proxy for the value of technology. See, for example, Thomas Horst, op.cit.

4/ Theoretically, the marginal cost of developing technology should be equal to the expected value of the marginal returns to technology. But even if this equality holds, it does not imply that the total costs of developing technology bear a close relationship with the value of technology developed.

Where technology is licensed to a nonaffiliated foreign recipient, data on the market value of the technology transferred may be available. However, as Richard Caves has noted, the market for the licensing of technology is the "one about which our ignorance is great concerning the extent of competition and the rationality of pricing decisions." 1/ Also, data necessary to link these transfers with trade flows and with foreign and domestic production of the products involved are not available in sufficient detail. Hence, it is difficult to estimate the impacts of these technology transfers on the U.S. economy.

Another approach to measuring the amount of technology transferred is the "resource cost" approach suggested by Arrow 2/ and empirically constructed by Teece. 3/ Arrow suggests that the cost of information transfer strongly influences the international diffusion of technology. Teece focuses on the cost of transferring "unembodied" knowledge. 4/ He identifies two groups of factors which influence transfer costs: (1) Those associated with the degree to which the transferor understands the technology; and (2) those identifying the technical and managerial competence of the transferee. It should be noted that the cost of transferring technology may also be affected by factors which are not related to technology differences among countries, such as costs of translating languages, or transporting goods; but these costs can be separated out to some extent. The cost of transferring technology may be as good a proxy for the value of technology transferred as any other proxy available. 5/ However, the total costs of transferring technology may be quite different from the total value of the technology transferred.

There exist various problems in measuring the amount of technology transferred. For example, consider a situation where a U.S. company builds a plant in Brazil to make modern tractors which have not been produced there. It appears that there has been a technological transfer, as tractors being produced there were much less "sophisticated." The fact that a U.S. firm may be the first to produce a "more modern" tractor may or may not represent a technology transfer. It could be that the technology already existed in Brazil, but was not being incorporated owing to capital shortages. Thus, what at first appears to be a technological transfer may actually be a transfer of sorely needed capital.

1/ Richard E. Caves, "Effect of International Technology Transfers on the U.S. Economy" The Effects of International Technology Transfers on U.S. Economy, National Science Foundation, Washington, D.C., July 1974, p. 36.

2/ Kenneth J. Arrow, "Classificatory Notes on the Production and Transmission of Technological Knowledge," American Economic Review, Papers and Proceedings, vol. 52, May 1969, pp. 29-35.

3/ D. J. Teece, "Technology Transfer by Multinational Firms: The Resource Cost of Transferring Technological Know-How," The Economic Journal, vol. 87, No. 346, June 1977, pp. 242-261.

4/ "Unembodied" knowledge is information needed to effectively use the transferred physical equipment.

5/ This approach to measuring the value of technology transferred resembles in concept the use of the costs of developing a technology as a proxy for the value of the technology and is subject to some of the same problems. See Caves, op.cit.

Production characteristics of the host country are important when using data on payments for technology to determine how much technology is being transferred. Because countries vary in terms of their levels of technological knowledge, a technology transfer from the United States to a developed country may represent only a very small technological advance for the host country, whereas the transfer of that same technology to a developing country may represent a very substantial technological advance for the host country. The true measure of any such technological gap may not be represented in the price system, for a technological development may be much more "usable" for a more advanced country than for a less advanced one. The technological gain in the more advanced one, for example, may be worth more there because it is labor saving in a country which is labor scarce relative to the less advanced country (which is assumed to be labor abundant). Thus, while a higher price paid by the more developed country may be a good approximation of the value of the additional technology, it would not reflect the relative amounts of technology being transferred to the developed and the developing countries. 1/

Thus far this report has been concerned with outward flows of technology. There are also important inflows of investment and technology from abroad. Data are available for fee and royalty payments and receipts by U.S. firms and are presented in table 1. Although the data on fees and royalties seem to indicate that technology outflows are much more important than inflows, they must be interpreted with care because they do not include all the ways in which payments are made for technology transfers and because they include payments for past transfers as well as current transfers. The data indicate that about one-fifth of total receipts of fees and royalties are from nonaffiliated foreign firms, and that receipts of fees and royalties are about ten times greater than payments. The data also indicate that, like U.S. trade and U.S. foreign investment, most U.S. licensing transactions occur with Canada, Japan, and Western Europe.

Three principal problems in measuring international transfers of technology have been discussed: (1) Identification of those transactions, such as trade or foreign investment, which actually contain a technology transfer;
(2) separating out and measuring payments made for the technology component of export and investment transactions; and (3) identification of the real flows of technology. In most cases, we have seen that proxy measures of technology transferred are subject to large and unknown errors. In some cases, better data collection would improve our ability to measure technology transferred.

1/ These observations of relative technological differentials concern the meaning of price of technological transfer and as such do not constitute a definitional problem so much as a measurement problem. There are many factors that affect prices; thus, should one identify the price of a technological transfer, care should be used in interpreting what the price represents. If some way of defining common units of technology can be reached, then a conversion into price per unit of technology can be expressed. The basic problem is the decomposition of the total value of the technology transfer into price and quantity components.

Table 1

Fees and royalties: payments and receipts in 1976 and 1977 (in millions of dollars) 1/

	1976	1977 2/
Total Receipts	4,302	4,590
From Affiliated Foreigners	3,472	3,678
From All Others	830	912
Total Payments	471	451
To Affiliated Foreigners	276	250
To All Others	195	201
Western Europe:		
Total Receipts	2,083	2,263
From Affialiated Foreigners	1,700	1,848
From All Others	383	415
Total Payments	319	328
To Affiliated Foreigners	150	154
To All Others	169	174
Eastern Europe:		
Total Receipts	20	22
From Affiliated Foreigners	-	-
From All Others	20	22
Total Payments	1	1
To Affiliated Foreigners	-	-
To All Others	1	1
Canada:		
Total Receipts	673	711
From Affiliated Foreigners	633	668
From All Others	40	43
Total Payments	142	131
To Affiliated Foreigners	135	124
To All Others	7	7

Table 1 (cont'd)

	1976	1977 2/
Latin American Republics and Other Western Hemisphere:		
Total Receipts	360	399
From Affiliated Foreigners	299	331
From All Others	61	68
Total Payments	31	9
To Affiliated Foreigners	26	4
To All Others	5	5
Japan:		
Total Receipts	498	540
From Affiliated Foreigners	257	283
From All Others	241	257
Total Payments	-24	-26
To Affiliated Foreigners	-36	-38
To All Others	12	12
Australia, New Zealand, and South Africa:		
Total Receipts	248	255
From Affiliated Foreigners	202	206
From All Others	46	49
Total Payments	0	-1
To Affiliated Foreigners	-1	-2
To All Others	1	-1
Other Countries in Asia and Africa:		
Total Receipts	434	400
From Affiliated Foreigners	381	342
From All Others	53	58
Total Payments	1	
To Affiliated Foreigners	1	8
To All Others	-	1

1/ Represents U.S. receipts and payments for the use of intangible property or rights, such as patents, techniques, processes, formulas, designs, trademarks, copyrights, franchises, manufacturing rights, service charges, and film and tape rentals.

2/ Provisional estimates.

Source: Survey of Current Business, March 1977 and March 1978.

C. The Economic Impact of Technology Transfers

Overview.--Assuming that problems of definition and measurement of technology and its international flows can be resolved, then the question of interest becomes one of ascertaining the impacts of technology transfers on the U.S. economy. These impacts result from price and income changes which occur in the economy of the recipient country. 1/ Presently, the effects of these changes in the recipient country generate much interest in terms of the structural changes in the country's economy and the changes in the volume and composition of the country's international trade flows. Likewise, the repercussions of U.S. technology transfers abroad could be reflected in structural changes in the U.S. economy as well as in changes in U.S. trade flows.

Although the range of effects can be described on a theoretical basis, it is another problem entirely to measure such effects. First, current data collection does not measure technology transfer as such. However, even if improvements were made in measuring transfers, there still remains the problem of deciphering their effects on the U.S. economy and on U.S. trade. For example, we do not know the time required to lapse before the varied effects are reflected or embodied in U.S. output, employment, or trade statistics. It is difficult, if not impossible, to identify the range and magnitude of effects that may be associated with one technology transfer transaction. The required analysis cannot be accomplished simply by drawing on improved trade or investment data.

1/ The introduction of a technological change in the host country should first manifest itself by expanding the production capabilities of the affected industry, causing changes in factor prices and product prices. If sufficient data are available, then several hypotheses concerning technological change should be empirically testable. For example, the relationship between factor savings and trade could be explored. If the technology can be determined to be capital saving or labor saving and the relative factor scarcity in the host country ascertained, then one could hypothesize what trade effects and income effects should occur and then empirically test this hypothesis. Suppose that the technological change makes a piece of capital equipment more productive (i.e., it is capital saving) and that capital is the relatively scarce factor in the country. Theoretically, products intensively using the relatively scarce factor face considerable import competition. Hence, a technological change favoring capital should make the capital-intensive product more competitive with imports, and thus it would be considered as import substituting.

If the technological change affected products which are labor intensive, then it would be considered as export stimulating in this particular country. Thus, the nature of the technological change should affect the trade pattern of the host country.

Additional effects of the transfer of technology on the host country should also be investigated. Secondary effects may be quite important. For example, a product produced by a new technological procedure may require imports of a particular input not previously used. There are likely to be income-generating effects of the technological transfer, effects which in turn may lead to a change in demand for imports. Price effects may be important, for they may result in change in the demand for substitutes. Thus, a complete analysis of the impact of the technology change on the host country would encompass a number of price and income effect and how these affect the country's pattern of trade.

<u>General Effects</u>.--The trade flows affect U.S. trade and production patterns, and consequently they should have price and income effects in those industries affected by these changes. For example, technology transferred by the United States to Mexico should have a price (and production) effect in the industry affected by the technological change. The products thus affected by this change should then be available to both the United States and Mexico, probably reflecting price adjustments. 1/ Price changes in the host country's trading goods should then lead to price and volume changes in U.S. exports and imports competing with the host country's products affected by the technology transfer. 2/ A framework for analyzing the impact of these changes in the United States needs to focus, at a minimum, on the effects on U.S. trade patterns and the degree to which such effects are the result of technology transfer.

<u>Net Income Effects</u>.--In addition to the impact on the United States resulting from production and price effects abroad, there are also income effects which should be considered. Presumably, the technology transfer generates additional income in the host country, in terms of possible increased profitability in the short run, increases in employment of domestic resources, and the potential for expanded markets domestically and internationally. This additional income due to the technology transfer will be offset to some extent by payments made to the United States as the seller of the technology. Hence, there will be a net income effect in the host country which is likely to manifest itself in terms of a demand change for imports, which may lead to a change in U.S. (and other country) exports.

Some of the reverse income effects should occur in the United States, where possible income losses due to decreased sales and employment will be balanced by receipts from the technology transfer. U.S. demand for imports is likely to change to the extent that income is altered.

Another income effect could result from changes in the exchange rates and in U.S. terms of trade which could be caused by the technology transfer. Findlay and Grubert have shown that a technological innovation in a country theoretically may reduce that country's income by changing its terms of trade, even if the technology is not transferred. 3/

<u>Income Distribution Effects</u>.--Although these price and income effects are probably the most easily quantifiable, there exist other aspects of technology transfer which may be of considerable importance. For example, the net income effects, whether positive or negative, in the host and in the U.S. economies are likely to have distributional impacts that are important. In the U.S. economy, those sectors that were the sellers of technology are likely to see their incomes increased, while those sectors that are adversely affected by the new foreign competition resulting from the technology transfer are likely to find their incomes falling. Theoretically, if there has been a net positive income change for the economy as a whole, those sectors that experienced income increases can compensate those sectors that experienced income losses until every sector is at least as well off as before the

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1/ This is particularly likely if the technology change affects the process used in the production of the products.

2/ It should be remembered that both competing products and inputs are affected owing to changing demand for products (or processes).

3/ Ronald Findlay and H. Grubert, "Factor Intensities, Technological Progress, and the Terms of Trade," <u>Oxford Economic Papers</u>, February 1959, pp. 111-121.

technology transfer occurred. However, an efficient income-transfer mechanism is required to assure this result. 1/

Employment Considerations.--The net income and income distribution effects will have their parallel in impacts on employment as a result of the technology transfers. The direction of the employment changes will be the same as that of the net income effect (leaving aside for the moment possible distribution effects). With all other influences remaining constant, a negative income effect results in decreases in total employment, and the reverse occurs for a positive income effect. However, distributional effects may occur which can reinforce or offset the net income effects. Labor will be affected to the extent that the relative labor-intensity of industries affected by the technology transfer differs from other industries in the U.S. economy. 2/ For example, suppose a particular technology change benefits an industry which is not as labor-intensive as the remaining industries in the U.S. economy. In this case, the distribution effect would be in favor of factors of production other than labor.

It should be noted that there also exists for labor an additional effect, regardless of the impact of net income and distributional effects. Any change induced by technology transfers which affects industry production patterns probably leads to labor market adjustments, which are associated with some costs. Adjustment costs for labor arise because of the impact of negative income effects and because of any distributional effects. That adjustment costs always arise in the latter case is due to the lack of complete geographical mobility in labor markets and to the lack of complete substitutability of labor skills among industries.

Other Considerations.-- In addition, if a transfer of technology from the United States does not occur, there may be a loss of income to the seller, but this does not necessarily imply that the country desiring the technology does not obtain a competitive technology elsewhere, or develop a domestic alternative. Hence, the net long-run effect if the United State does not transfer the technology may be a loss of income to the United States, although the short-term effect may be just the opposite, particularly if U.S. firms do not have a monopoly on the technology. Another relationship is that of the effects of technology transfer abroad via trade, foreign direct investment, and licensing on technological innovation. As Stobaugh has pointed out:

> A plausible hypothesis is that the possiblility of a firm's exporting, making foreign investments, or selling licenses would induce it to engage in certain R&D programs that would not be economical if the U.S. market were the only one considered; thus, U.S. technological innovation would be increased and in turn U.S. economic growth would increase. 3/

1/ Such a mechanism would also require that those factors of production adversely affected be compensated by those which benefited from the technology transfer. Shifts in sector demand are likely to cause shifts in factor demands. See the letter of concurrence from the U.S. Department of Labor.

2/ The distributional effect abstracts from net income effects (i.e., it assumes incomes do not change).

3/ See Robert B. Stobaugh, "A Summary and Assessment of Research Findings on U.S. International Transactions Involving Technology Transfers," The Effects of International Technology Transfers on U.S. Economy: Papers and Proceedings of a Colloquium, National Science Foundation, Washington, D.C., July 1974.

This hypothesis suggests that international technology transfer, by enlarging the market for products incorporating technological change, may stimulate additional R&D outlays.

However, in some cases technology transfer may lead to reduced innovative activity in the technology exporting country, especially if these transfers contribute to important declines in output of a given product line. For example, the United States has transferred technology abroad in a wide range of consumer electronic products, including transistor radios, home hi-fi amplification equipment, color television, and home tape recorders. These transfers may have contributed to increased import competition and decreased domestic output of these products, as well as increased innovative activity in these industries abroad. Such evidence as the home videotape recorder innovations being made abroad have led some to conclude that reductions in domestic output may have caused reductions in domestic innovations by causing reduced R&D.1/

Thus, technology transfer abroad should be viewed as a dynamic process which may affect the U.S. economy in different ways, and an analysis which views only a particular aspect of its impact can at best only give a partial and incomplete view of the consequences for the U.S. economy.

D. U.S. Trade Focus: A Range of Possible Effects

Technology-Gap Effect.--The transfer of technology resulting in the new foreign production of a specific product or product line is usually assumed to displace at least some potential foreign demand for imports of that product. By filling a "technology gap," the transferor is believed to erode the originating country's comparative advantage. The operation of this effect, however, as empirically determined by Adler and Hufbauer, 2/ depends on whether the transfer augments foreign production or merely replaces earlier production. In the former and more likely case, the transfer may serve to displace exports from the country of the transferor, but in the latter case there would be no export displacement. Accurate and comparable data about various aspects of production and trade of both the transferring and recipient countries (see following subsection) would be required for analysis. In addition, any realistic assessment of the technology-gap effect would also

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1/ See, for example, the testimony by Dr. Jack Baranson before the Senate Subcommittees on Science, Technology, and Space and International Finance concerning the competitiveness of U.S. high technology products on May 16, 1978. Dr. Baranson cited the retrenchment of domestic companies in the industry.

2/ F. Michael Adler and Gary D. Hufbauer, Overseas Manufacturing Investment and the Balance of Payments, U.S. Treasury Department, Tax Policy Research Study No. 1, 1968.

depend upon related factors such as the operation of tariff and nontariff barriers on imports, the possibility of alternative sourcing of the technology, and the possibility of imitating the technology without license.

Associated-Export Effect.--As associated-export effect occurs when the transferring firm uses the marketing organization of the recipient firm to expand its export sales of a range of goods, both related and unrelated to the technology transfer. Such export sales would be additional to any sales of components or parts that may be supplied under the technology-transfer arrangement. This effect would probably have its greatest importance when direct investment occurs.

Supply-Growth Effect.--Technology transfers may affect supply conditions in the affected industry and may also stimulate growth of production in the recipient country and lead to increased competition for the transferor. Such increased competition may have a net negative effect on the trade balance of the transferring country, particularly after the technology transferred becomes more standardized.

Demand-Growth Effect.--The demand-growth effect may occur when technology transfers stimulate economic growth in the recipient country. Not only can the volume of aggregate trade be expanded in the process, but also the pattern of demand may be altered to one more like that of the transferring country or other advanced industrial countries. If the demand-growth effect occurs, exports of the transferring country's products should increase, at least in the short run until new products or processes became more standardized and widely established in the recipient country.

Inter-Industry Effects.--These effects occur when industries change their demand for factor inputs as a result of technology transfers. These changes in demand for factor inputs may result in production and price changes in the factor-supplying industries. Conversely, the technology-affected industries may be factor suppliers to other industries, in which case the latter are affected by changes in the prices of their inputs.

E. An Approach Used to Analyze the Effects of Technology Transfers on U.S. Trade, Production, and Employment

The purpose of this section is to provide a brief and fairly nontechnical discussion of the methodological problems encountered in estimating the impact of international technology transfers on U.S. trade, production, and employment. It presents a general framework for the analysis of the impact of technology transfers on trade of individual industries, and how this may affect the economy as a whole.

The Framework.--An approach to estimating the direct impact of technology transfer on U.S. trade would be to measure the effect of the transfer on foreign production capabilities and the price and quality of the foreign product, and to then estimate the effects of these changes in foreign supply on U.S. trade. This would be a major undertaking and would necessitate a fairly large general frame of reference, or model.

For example, consider a product for which U.S. producers have a technological advantage in production and which they export. The transfer of technology abroad may create competitive foreign producers which would supply part of the market for the U.S.-produced good. To estimate the impact of the technology transfer on U.S. exports, the impact of the transfer on the price and quality of the foreign good would have to be determined. Then, the impact of these changes in foreign competition on the demand for U.S. exports would need to be determined. Theoretically, the levels of U.S. exports of the good involved could be estimated on the basis of no technology transferred and compared with actual exports. However, accurate assessment should include consideration of whatever changes occurred in other factors that influence the supply or demand for U.S. exports of the product. All of these steps are necessary to determine the specific impact of the technology transfer. This procedure does not account for important side effects of technology transfer which need to be estimated to determine the total impact on U.S. trade, such as the associated export, demand-growth and innovation-stimulus effects. 1/

Another consideration is that in setting up a new production facility in a host country, technology from several different foreign sources may well be employed. These multicountry sourcings of technology may occur either when a production facility is being established in a host country by a multinational corporation or when a host country purchases the technology through licensing arrangements. 2/ In either case the problem of attempting to assess the role of any U.S. technology in the production facility would be greatly compounded.

1/ A list of these side effects and an explanation as to how they arise is given by Tom Horst in "The Impact of U.S. Investment Abroad on U.S. Foreign Trade," The Brookings Institution, January 1974 (mimeo).

2/ In establishing its new assembly plant in South Africa, Ford Motor Co. brought in engineers and technicians from five different foreign countries, including the United States. See Jack N. Behrman and Harvey W. Wallender, Transfers of Manufacturing Technology Within Multinational Enterprises, Cambridge, Mass., 1976, p. 54. The Soviet Union obtained technology from at least five different countries, including the United States, for its Kama factory. See Herbert S. Levine, et al., Transfer of U.S. Technology to the Soviet Union: Impact on U.S. Commercial Interests, Stanford Research Institute, Febuary 1976, prepared for the U.S. Department of State, pp. 154-5 and p. 191.

Data Shortcomings.--As indicated, the analytical framework discussed above would require a great deal of data, much of which is not readily available. Measurement of the actual amount of technology being transferred from the United States to other countries is the first information required, and this information would be needed by product sector classification and by the type of transfer. Second, the specification of certain demand and supply relationships would be necessary. To estimate the supply functions of the foreign industries that are the recipients of the U.S. technology, data on foreign production and prices, as well as factor costs, would be a prerequisite. At present, these data exist on a product-sector basis in many industrialized countries, but are not, in general, directly comparable with U.S. production, price, and trade data. Third, secondary effects in the host country might be estimated if input-output relationships were calculated for the country. Fourth, to ascertain trade effects, domestic and international demand functions would have to be constructed, and these functions would require, at a minimum, domestic and international price data as well as real income levels. Fifth, the effects of changes in trade on U.S. consumption of the imports, and production of the substitutes for these imports, would involve specification of domestic demand and supply functions, which have already been constructed for several industries.

In summary, the major data problem, aside from measuring the flow of technology, appears to be in obtaining reliable price and factor costs for foreign countries which are on a disaggregated basis and which are comparable among countries. As might be imagined, to undertake to collect such a large amount of data, much of which probably does not exist, would be an enormous task.

The Problem of Alternative Hypotheses.--The determination of the impact of a technology transfer on foreign production capabilities raises the question of what might have occurred in the absence of the transfer. This alternate state of affairs cannot be observed, it can only be hypothesized, which is perhaps the most important reason why estimates of the effects of foreign direct investment and technology transfer on the U.S. economy are subject to large error and much dispute. Questions about the alternate state of affairs that must be answered include: In the absence of the transfer, is there an alternative source of the technology available for the prospective host country? If the transfer were prevented, how long would it take the prospective host country to develop the technology independently? 1/ One means of assessing what might have occurred without the technology transfer would be an estimation of the amount of time saved by filling the technology gap. 2/ Robert Stobaugh assumed arbitrarily that the production advantages

1/ For example, consider the licensing arrangement concluded between Piper Aircraft and a Brazilian firm to manufacture civilian passenger aircraft. In the absence of the Piper Aircraft contract, the Brazilian firm may have obtained a similar contract from European sources. Although the Piper contract may have displaced exports of some U.S.-manufactured Piper aircraft, some exports may have been lost anyway if a foreign firm obtained the contract. A description of this technology transfer and the alternatives for Brazil is given by Jack Baranson, "International Transfers of Industrial Technology by U.S. Firms and Their Implications for the U.S. Economy," prepared for the Bureau of International Labor Affairs, December 1976.

2/ Examples showing how these time considerations are used in determining the impacts of technology transfers on foreign production capabilities are given by G. R. Hall and R. E. Johnson, "Transfer of United States Aerospace Technology to Japan," The Technology Factor in International Trade, edited by Raymond Vernon, pp. 305 and 358, and Alvin Harmond, The International Computer Industry, Cambridge, Mass., 1971, pp. 39-44.

provided by a particular technological advantage faded and were completely gone within 6 years. This assumption substantially influenced the results of his study. 1/

Estimating Employment Effects from Production Effects.--Estimates of the effects on employment would be very difficult to determine even if good estimates of the effects on production were available. For example, suppose a particular technology transfer decreases production in one industry. The decreased demand for labor will probably result in some decrease in employment and some decrease in wages. The tendency for employment to decrease, compared with the tendency for wages to decrease, will depend on the nature of the particular industry's demand for labor and on the conditions of labor supply for the particular occupations involved. Any employment changes in the particular industry under consideration would be accompanied by changes in other industries. These could be estimated using input-output analysis. If production increases should occur, then the reverse effects would be expected.

Exchange Rates.--It should be recognized here that the above discussion of the impact of technology transfer on trade has assumed fixed exchange rates. Theoretically, if U.S. technology transfers in an industry tend to affect adversely the competitive position of that industry and cause the industry's trade balance to deteriorate, then there should be a market devaluation of the U.S. currency. One should note that even a significant deterioration in the trade balance in a particular industry would have only a negligible effect on the exchange rate since exchange rates are influenced by the entirety of U.S. trade and capital flows as well as by economic and political forces acting throughout the world. Furthermore, any minimal devaluation of the dollar that does occur because of a deterioration in the competitive position of an industry would have a similarly minimal compensating effect on that industry's competitive position in world markets. The effects of the minimal devaluation will be spread throughout the economy. Factors of production in other sectors of the economy (particularly the export industries and import-competing industries) will realize marginal income gains that tend to offset the income losses experienced by factors of production in the industry that lost its competitive position because of technology transfers. 2/ It should be emphasized, however, that these exchange-rate effects are so negligible that for the purposes of analyzing the effects of technology transfer on a particular industry, the assumption of fixed exchange rates easily can be maintained. Whether or not this same assumption can be maintained when analyzing the totality of U.S. technology transfers is, presumably, the essence of the concern about these transfers.

1/ Robert B. Stobaugh, "How Investment Abroad Creates Jobs at Home," Harvard Business Review, Sept.-Oct. 1972, pp. 118-126.

2/ One way in which technology transfers may have an impact is by the positive balance of fee and royalty payments having an effect on exchange rates, which in turn could have an effect on the trade account.

F. Summary

Any review of policy towards technology transfer should recognize that the effects on U.S. trade, production, and employment may vary greatly by industry. Since various specific transfers may have very different effects, they should probably be evaluated on an industry basis. However, even on an industry level, there is serious question whether the economic effects of technology transfer can be extracted from existing or even improved data on U.S. trade, licensing, and investments. First, there is no consensus on what is meant by technology, the technology-transfer process, or advanced-technology industries. Second, existing data-gathering efforts do not focus on measuring the value, volume, or direction of U.S. technology transfers abroad. Hence, it becomes extremely difficult to identify what loosely may be termed as the technology component of U.S. transactions in international trade, investment, and licensing. Third, the effects of U.S. technology transfers on the U.S. economy would be difficult to trace through trade or investment data since the time lag of the effects on U.S. production, employment, or trade figures is not known. Finally, the question of isolating the production, employment, and trade effects associated with any particular technology transfer remains unresolved.

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III. THE TRADE COMPETITIVENESS OF HIGH-TECHNOLOGY INDUSTRIES

The previous chapter has outlined the many methodological and data problems that would be involved in any attempt to measure the economic impact of technology transfers. There have been few studies that have addressed the question of the importance of this impact. The studies that have been done were limited in scope, often concentrating on one firm or a single industry, and they largely concluded with qualitative answers using evidence that might be described as speculative. Given the paucity of economic evidence linking technology transfer and export competitiveness, one might ask why there is such concern that the transfers are detrimental to the U.S. economy. One reason might be that several economic studies have shown indications of a relationship between high technology levels and export competitiveness. If these studies reflect reality and if U.S. technology is being exported at a faster rate than it is being developed or imported (an important, unanswered question), then it may not be such a great leap to infer that the transfers are gradually eroding the competitive position of the United States. The present chapter will discuss some of the studies that indicate a linkage between technology and trade competitiveness.

A. Competitiveness

Before examining attempts that have been made to relate technology to trade competitivenes, a few comments on the interpretation of the term "trade competitiveness" are in order. The popular meaning of the term is often a reference to the trade balance of a nation. The connotation is that competitiveness requires positive trade balances, an idea not unlike that of 18th century mercantilists. Comments on the transformation of the U.S. trade position from one of a net positive to a net negative position are often accompanied by statements that the United States has "lost its competitive edge" or is "no longer competitive in world markets."

In discussions of trade competitiveness, various measures of trade balance have been used as indicators of trade performance. 1/ These reflect concerns about the relative trade performance of different industries within a country or the relative trade performance of the same industry among countries rather than about aggregate trade balance figures. The study of trade competitiveness involves the examination and testing of various factors that, theoretically, explain the structure of a country's trade. In addition to labor, capital, and raw material endowments, other considerations are involved in explaining the volume, value, and direction of trade. These include such variables as tariff barriers, physical barriers (e.g., distance), institutional arrangements (e.g., common market schemes), labor skills, and technology.

1/ Besides the simple trade balance (i.e., exports minus imports), other indicators of trade performance (e.g., competiveness) that are used in testing trade theories include export trade shares, the ratio of exports to imports, the import/consumption ratio, and the export/production ratio.

B. Representative Studies

A few studies have been reviewed here for what they have to say regarding the role of technology as an important determinant of the structure of trade flows. 1/ In a 1971 article, Robert Baldwin reviewed several studies of the determinants of the U.S. trade structure and tested theories of these determinants using new data. 2/ Baldwin looked at several possible explanatory variables to find the relationship between them and net trade flows (i.e., exports minus imports). What he found with regard to R&D activities was that they were "much more important in export output than in import-competing production." 3/ In general, he concluded that simple trade theories that rely on only one or two explanatory factors (e.g., labor and capital per worker) should be discarded in favor of more complex models that account for such factors as labor skills and technological differences. 4/

Thomas C. Lowinger focused on the importance of the technology factor in U.S. export performance. 5/ Lowinger tested several factors to find what their relationship was to (1) U.S. industrial export shares in world markets, and (2) the changes in U.S. industries' relative export shares between 1960-62 and 1968-70. Lowinger found that "the technological intensity variable in its various forms turns out to be the single most potent explanatory variable of U.S. industries' revealed comparative advangage." 6/ Lowinger's choice of explanatory variables, other than measures of technology intensiveness, was not as large as other studies. He included the ratio of wages and salaries to industries' valued added, a measure of economics of scale, and an export-weighted measure of average foreign tariff rates on the industries' product.

Another study with a slightly different approach and different conclusions was reported by Katrak. 7/ In this study, Katrak related the relative performance of U.S. industry exports and U.K. industry exports in world markets to variables that measured relative human skill intensities, industry size, and R&D expenditures of the industries in the two countries. Katrak tested these variables using rank correlation analysis and multiple regression analysis. The R&D factor did not show a strong relationship to the export measures in either test. The human skills factor fared slightly better in the analysis and the industry size variable performed best of all.

1/ For a comprehensive review of economic studies of trade theories see G. C. Hufbauer, "The Impact of National Characteristics and Technology on the Commodity Composition of Trade in Manufactured Goods," The Technological Factor in International Trade, edited by Raymond Vernon, National Bureau of Economic Research, New York, 1970; or, more recently, Robert M. Stern, "Testing Trade Theories," International Trade and Finance: Frontiers of Research, edited by Peter B. Kenen, New York, 1975.

2/ Robert E. Baldwin, "Determinants of the Commodity Structure of U.S. Trade," American Economic Review, vol. 61, No. 1, March 1971, pp. 126-146.

3/ Baldwin, op.cit. p. 136.

4/ Baldwin, op.cit. p. 143.

5/ Thomas C. Lowinger, "The Technology Factor and the Export Performance of U.S. Manufacturing Industries," Economic Inquiry, vol. 13, No. 2, June 1975, pp. 221-236.

6/ Lowinger, op. cit. p. 229.

7/ Homi Katrak, "Human Skills, R&D and Scale Economies in the Exports of the United Kingdom and the United States," Oxford Economic Papers (New Series), vol. 25, No. 3, November 1973, pp. 337-360.

The more recent studies to be considered here are: (1) Multivariate Analysis of Industry Characteristics and Trade Performance in the United States, and (2) The Impact of Technological Innovation on International Trade Patterns. 1/ Both studies focus on examining the relationship between industry/product characteristics and trade competitiveness.

The methodology suggested in the multivariate analysis to investigate the international trade competitiveness of U.S. industries involves three steps: (1) Grouping of industries into categories based on certain level of competitive strength in international trade, (2) searching for characteristics that best discriminate among industries in terms of indicating their trade performance, and (3) relating the identified characteristics of the industries with trade competitiveness of U.S. industries. First, U.S. industries, based upon the values of their trade measures for the study year 1970, were grouped according to cluster analysis procedures. Two trade measures, export shares and trade balances, were chosen for industry classification to reflect the comparative advantage of U.S. industries. 2/ Ranges for the export shares and trade balances were selected to differentiate industry groupings by competitive performance. Four industry classifications resulted: (1) Highly export competitive, (2) somewhat export competitive, (3) somewhat import sensitive, and (4) highly import sensitive.

To ascertain which industry characteristics (e.g., R&D expenditures, the first date of trade, the number of scientists and engineers employed, and natural resource intensity) most effectively discriminated among the four groups of trade-competitive industries, discriminant analysis was used in the study. On the basis of the results of the discriminant analysis, the study developed a group ranking of all industries in terms of their competitiveness. Those industries identified as belonging to the highly export competitive group are listed in table 2.

The discriminant analysis is not useful in indicating causality. However, regression analysis was used to determine the significance of possible explanatory variables (i.e., the industry characteristics) in determining the trade competitiveness of U.S. industries. A major conclusion of the regression analysis was that the number of scientists and engineers engaged in R&D was associated with significant variations in terms of trade competitiveness.

1/ The former study, prepared by Wayne Simon, was published as Staff Research Study No. 8, Office of Economic Research, U.S. International Trade Commission, Washington, D.C., October 1976. The latter, prepared by Regina Kelly, was published as Staff Economic Report OER/ER-24, Office of Economic Research, Bureau of International Policy and Research, U.S. Department of Commerce, Washington, D.C. December 1977.

2/ Export shares related U.S. exports by TCSIC trade classification to exports of other countries. Weighted trade balance refers to an industry's trade balance divided by that industry's total trade.

For the concordance of TCSIC to trade and production classifications, refer to U.S. Tariff Commission, "Industry Characteristics Data--Definition and Derivation of Variables in Data Bank," (based on 4-digit ITC-SIC concordance), 1975 (mimeo).

Table 2.--Ranking of U.S. industries in terms of competitiveness groups

Highly Export Competitive Group

TCSIC No.	Industry/Trade Description
2034	Dehydrated fruits & vegetables
2041	Flour & other grain mill products blended & prepared flour
2042	Prepared feeds for animals & fowls
2043	Cereal preparations
2044	Rice milling
2091	Cottonseed oil mills
2094	Animal & marine fats & oils
2111	Cigarettes
2411	Logging camps & logging contractors
	Wood preserving
2445	Cooperage
2631	Paperboard mills
2812	Alkalies & chlorine
2818	Industrial organic chemicals, nec
	Agricultural chemicals, nec
2831	Biological products
2851	Paints & allied products
2861	Gum & wood chemicals
2893	Printing ink
2895	Carbon black
2899	Chemical preparations, nec
3031	Reclaimed rubber
3255	Clay refractories
	Nonclay refractories
3296	Mineral wool
3494	Valves & pipe fittings, except plumbers' brass goods
3531	Construction machinery
3533	Oil field machinery
3561	Pumps & compressors
3573	Electronic computing equipment
	Calculationg & accounting machines, except above office machines, nec
3581	Automatic merchandising machines
3585	Refrigeration machinery
3623	Welding apparatus
3672	Cathode ray picture tubes
3674	Semiconductors
3721	Aircraft
3722	Aircraft engines & engine parts
3729	Aircraft propellers & parts
	Aircraft parts & equipment, nec
3811	Engineering & scientific instruments
	Mechanical measuring devices
	Automatic temperature controls
3841	Surgical & medical instruments
3843	Dental equipment & supplies
3951	Pens & mechanical pencils
3993	Signs & advertising displays

Source: Office of Economic Research, U.S. International Trade Commission, Multivariate Analysis of Industry Characteristics and Trade Performance in the United States, Staff Research Study No. 8, Washington, D.C., October 1976.

To provide some insight on the pattern of trade in R&D-intensive goods, the findings of a recent U.S. Department of Commerce Staff Economic Report are summarized. 1/ The defined "advanced and industrial technology sectors" focused on the technical research and development component of technology, but not on the managerial one. In this respect, the report's findings may not fully reflect the trade patterns of advanced industrial technology fields.

In 1977, U.S. exports of manufactured goods accounted for approximately 66 percent of total U.S. exports. Approximately 41 percent of manufactured exports consisted of products with greater-than-average research intensities. (See table 3 for list of categories.) The above pattern distinguishes the United States from other industrialized nations whose research-intensive products typically have accounted for only 25 to 28 percent of manufactures exports. The research intensity of U.S. manufactures exports was found to be nearly 40 percent higher than that of the United Kingdom, 60 percent higher than France and Germany, and over 75 percent higher than Japan and the remainder of the OECD countries. 2/ The overall U.S. share of OECD trade in the designated technology-intensive products was nearly 75 percent higher than in non-technology-intensive products.

The study emphasizes, however, that factors other than research intensity or innovativeness have a strong influence on the volume and composition of U.S. manufactured exports. For example, the study suggests that price competitiveness, particularly as affected by currency realignments, may have strongly improved the export competitiveness of U.S. manufactured goods, even in the category characterized as technology-intensive. During 1968-71, a period when the dollar was generally considered overvalued, the expansion of U.S. exports of research-intensive products lagged well behind the OECD average, and was notably outpaced by Japanese research-intensive exports (which grew at more than twice the U.S. rate). During 1971-74, however, the growth rate for U.S. exports of these products slightly exceeded the OECD average. Indeed, only France outperformed the United States in the export growth of its research-intensive products.

1/ R. Kelly, op.cit. For another treatment which uses a more aggregative classification of industries, but includes more exporting countries and identifies importing partners, see Aho and Carney, op.cit. Their paper also examines trade over the longer period from 1965 to 1976 in order to identify changes in trends.

2/ It should be noted that research-intensity ratios derived from U.S. domestic production were applied to the trade of other countries. The use of U.S. R&D ratios assumes that the relative R&D position of given products is similar in different countries and that the mix of goods within each individual product group is also comparable. R. Kelly, op. cit., p. 16.

Table 3.--Description of product classes by technology classification, 1968-70

SIC Code	Product Description
Excluded	
1925	Guided missiles and spacecraft
Technology-intensive	
366-7	Communication equipment and electric components
372	Aircraft and parts
357	Office, computing, and accounting machines
383-7	Optical and medical instruments; photos, watches
283	Drugs and medicines
282	Plastic materials and synthetics
351	Engines and turbines
287	Agricultural chemicals
19 less 1925	Ordnance, except guided missiles
381-2	Professional, scientific, and measuring instruments
362	Electrical industrial apparatus
281	Industrial chemicals
365	Radio and TV receiving equipment
Non-technology-intensive	
*352	Farm machinery and equipment
*361	Electric transmission and distribution equipment
*371	Motor vehicles and equipment
*363-4,369	Other electrical equipment and supplies
*353	Construction, mining, and related machinery
*284-6,289	Other chemicals
34	Fabricated metal products
30	Rubber and plastic products, n.e.c.
*354	Metalworking machinery and equipment
*373-5,379	Other transportation equipment
*355-6,358-9	Other nonelectrical machinery
23-27,31,39	Other manufactures, n.e.c.
32	Stone, clay, and glass products
333-6,3392	Nonferrous metals and products
331-2,3391,3399	Ferrous metals and products
22	Textile mill products

* Denotes product groups with below-average technology intensity which are generally included in definitions of "technology-intensive products" based on 2-digit SIC analysis.

Source: Office of Economic Research, Bureau of International Policy and Research, U.S. Department of Commerce, Alternative Measures of Technology-Intensive Trade, Staff Economic Report OER/ER-17, Washington, D.C., September 1976.

Fluctuations in U.S. export growth rates for R&D-intensive goods may be in part due to structural differences of the U.S. economy and the economies of other OECD countries. There are differences in the reaction of each country's economy to recessions and to currency realignments. The United States is not as reliant as are most countries on exporting for its economic well-being. For many OECD countries, however, the continued growth of their national economies depends to a much greater extent on export expansion. On the firm level, because the United States has a large domestic market and has traditionally not been export oriented, U.S. businesses have been relatively less sensitive to export market considerations (e.g., currency realigments and international marketing) than have been those of Japan or West Germany.

The importance of R&D-intensive exports as a dependably positive element in the overall balance of U.S. trade in manufactures is shown in table 4. These data depict the U.S. trade balance in research-intensive goods as being positive, thus expressing the importance of R&D-intensive industries in the case of trade competitiveness. While this implies a need for the United States to retain its technological edge, such data do little to isolate the effects of the technology factor.

Table 4.--U.S. trade in manufactures by R&D intensity classification 1/
(in billions of dollars)

	1968	1971	1972	1973	1974	1975	1976	1977
R&D Intensive Manufactures:								
Exports	9.6	13.2	14.1	19.0	26.6	28.0	31.2	33.4
Imports	3.9	6.6	8.5	10.6	12.9	12.3	17.0	19.6
Balance	+5.7	+6.6	+5.6	+8.4	+13.7	+15.7	+14.2	+13.8
Other Manufactures:								
Exports	14.2	17.2	19.6	25.7	37.0	43.1	46.1	47.1
Imports	16.7	23.8	29.3	34.4	42.4	38.8	47.8	57.7
Balance	-2.5	-6.6	-9.7	-8.7	-5.4	+4.3	-1.7	-10.6
Total Manufactures:								
Exports	23.8	30.4	33.7	44.7	63.5	71.0	77.2	80.5
Imports	20.6	30.4	37.8	45.0	55.2	51.1	64.8	77.2
Balance	+3.2	0.0	-4.1	-0.3	+8.3	+19.9	+12.4	+3.3

1/ Based on SITC classifications. See Kelly, op.cit., for methodology for converting SIC to SITC classifications (Technical Appendix).

Source: U.S. Department of Commerce.

C. Alternative Measures of Technological Competence

Besides measures of R&D expenditures and R&D personnel (the most common proxy measurement of technology content), there are other indicators of technological competence that may be useful in inter-country and inter-industry studies of the role of technology in trade competitiveness. However, measurements of these alternative proxies generally are not collected with the degree of disaggregation available in the R&D measurements. In addition, most of them have other shortcomings that bring into question their accuracy. For example, patent data might be used as an indicator of the inventive output of countries. Some problems with these data are, first, they do not include all innovations, for often companies prefer to keep their inventions secret and do not patent them, and second, criteria for awarding patents differ from country to country. Another method to gauge the relative innovativeness of scientists in different countries is by studying the contributions made to scholarly publications by each country's scientists. Here, however, one's sample is apt to be biased by the journals selected and by the fact that publication policies differ from country to country. The above two statistics plus such data as the number of Nobel prize winners and the number of scientists participating in international meetings give some indication of each country's relative creativeness, but these statistics are too crude to be used with confidence in quantitative studies of trade and technology. 1/

Perhaps a more promising approach to relate technical creativeness to trade competitiveness would be to use IP indexes as the technology proxy. IP's were discussed above in II. 2/ Although these indexes have the same problem as R&D indicators when making comparisons across industries, they should show a closer correlation to trade competitiveness (if the technology content/competitiveness relationship is real) than R&D indicators since R&D expenditures measure only resource inputs to technology innovation, wheras IP indexes show the results of the innovation process. To date, the use of IP indexes has been miminal. 3/ Collection of the data required to construct IP indexes is quite laborious and expensive. Carefully constructed surveys as well as researchers with technical and economic training are required. A well-constructed series of IP indexes would allow the testing of the importance of the variable in U.S. trade flows. Before intercountry comparisons could be made, corresponding IP data from other countries would be required.

1/ The data mentioned here and other similar data are collected and published annually by the National Science Board in Science Indicators, 1976, National Science Foundation, Washington, D.C., 1977.

2/ See page 11.

3/ Besides the Gellman study cited above (see footnote 2, p. 11.), another use of an IP index has been undertaken by Cohen, Katz, and Beck in their study of the pharmaceutical industry, Benjamin I. Cohen, Jorge Katz, and William T. Beck, "Innovation and Foreign Investment Behavior in the U.S. Pharmacentical Industry," National Bureau of Economic Research Working Paper 101, August 1975.

D. Summary

The inability of traditional theories of comparative advantage to explain the competitive strength of the United States in many manufactured products has focused attention on the role of technological innovation in U.S. trade performance. Some of these studies have found a positive and significant relationship between the international competitive position of the United States and the relative technology content of U.S. exports as determined by R&D indicators. This does not imply, however, that the studies agree on what U.S. trade trends are in technology-intensive products, nor on the relative importance of technology to a favorable U.S. trade position.

A comparison of two studies examined in detail here, one by ITC and the other by the Department of Commerce, highlights the difficulty of defining technology-intensive trade: differences in qualifying criteria, data sources, or merely the level of aggregation at which the study is conducted lead to different characterizations. The most common method of defining technology-intensive trade rests on the inter-industry distribution of some R&D-related activity, such as expenditures or scientists and engineers employed. As previously stressed, however, these measures are subject to a number of shortcomings when used as indicators of relative technological competence. Other frequently cited indicators, such as patent activity, are also limited in their usefulness. One promising alternative to the R&D approach is the innovative process (IP) approach.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

There are important conceptual and measurement problems encountered in attempting to determine the effects of technology transfers on U.S. trade, production, and employment. Problems which have been considered in this report include how to define and measure technology, technological change, advanced industrial technology fields, and technology transfers, and how to determine the effects of technology transfer separately from other economic factors influencing U.S. trade, production, and employment. These problems remain unresolved.

In addition to problems of definition and measurement, in order to determine the impact of a technology transfer, one must ultimately determine what would have occurred in the absence of these transfers. This alternative state of affairs cannot be observed, it can only be hypothesized, which is a very important reason why estimates of the impact of technology transfer are controversial and subject to large error.

Recent studies have linked the technological sophistication of an industry, as determined by R&D indicators, with its trade competitiveness. However, these linkages are still tenuous and have not been integrated into the larger framework of economic factors that influence trade flows. In particular, research and development expenditures, the most commonly used indicator of the technological sophistication of an industry, have not always been found to be a very reliable predictor of trade competitiveness.

B. Recommendations

In view of the state of art of research on the effects of technology transfer on U.S. trade, production, and employment, it is difficult even to make recommendations as to how to improve our knowledge of these effects. However, the feasibility of correcting some of the severe shortcomings in our current measures of technology transfer should be investigated. The Technology Transfer Subcommittee of the Interagency Committee on International Investment Statistics, currently chaired by the Office of Statistical Policy and Standards of the Department of Commerce, is in the process of conducting such an examination. Our own investigation uncovered the following areas for improvement:

1. Data collection on current sales and purchases of technology. Present fee and royalty data are for receipts and payments for the stock of all past technology transfers and hence do not tell us the relative size of current technology inflows and outflows.

2. Data collection on products involved and the quantity of foreign production when technology is licensed to a nonaffiliated foreign recipient. These data would be necessary in order to relate transfers of technology to nonaffiliated foreigners with the possible effects on U.S. trade. They may not be collectable because the United States would have no statutory authority over nonaffiliated foreigners.

3. Data collection on transfers of proprietary technology not paid for by fees or royalties. Examples of such transfers would include technology sold in exchange for equity in the receiving firms, technology traded in exchange for other technology, technology transferred to affiliates with no explicit fee or royalty charges, and "turnkey" operations.

4. Collection of a set of qualitative as opposed to quantitative data on technology transfers. A special survey would be needed. Exports could be classified as being new products in the recipient country, as having competition in the recipient country, and, if so, whether the substitutes are imported from third countries or produced domestically. If they are produced domestically, it would be worthwhile to know if they are produced by locally-owned or foreign-owned firms. Additional data might include questions on whether or not the process involved in the technology transfer is already present in the recipient country or if other foreign sources are available. Data might be collected on the number of transactions, the host country for each transaction, and the channel (for example, licensing to a nonaffiliated foreigner, or direct foreign investment) used to accomplish the transfer. Some description of the technology, including information on how long it has been available in the United States and how it might differ from similar technology available abroad would also be useful. The resulting set of data could then be used to ascertain how different product groups are transferred to different countries. Research could be done to investigate the economic and legal influences which account for such phenomena as why a particular product would be exported to one country whereas the technology it incorporates is transferred to a second country via foreign investment and to a third country via licensing.

ANNOTATED BIBLIOGRAPHY

This bibliography is intended to be used as a source of additional research published since the release of the National Bureau of Economic Research's Bibliography on Technology and Trade in 1975. The entries here are not all-inclusive. Also, the literature discussed in Chapter III of the report is not repeated here.

Baranson, Jack. International Transfer of Industrial Technology by U.S. Firms and Their Implications for the U.S. Economy. A Discussion Paper on International Trade, Foreign Investment, Employment. Washington, D.C.: U.S. Department of Labor, December 1976.

This reports the results of 25 case studies in 5 different industries (i.e., 5 case studies were done for each industry). The industries covered were aircraft, automotive, computers, consumer electronics, and chemical engineering. As a result of his research the author challenges the idea that U.S. corporate decisions regarding the sale of industrial technology coincide with and protect the interests of the U.S. economy. The implications for the U.S. economy that he sees are:

1) Management service contracts may cause a further erosion of U.S. production jobs in key industries;

2) These technological displacements could be troublesome:

   a) Under adverse domestic economic conditions;
   b) In the absence of improvement in labor market adjustment mechanisms;
   c) In an economy whose technologically dynamic sectors are not growing rapidly enough to absorb labor displacement from declining sectors;

3) A permissive posture in the release of front-end technology to foreign enterprises can lead to damaging consequences for other domestic producers in that industry;

4) Some evidence that U.S. firms are having more trouble in adjusting to technical change and are considering marketing their technology rather than doing the engineering for production

5) Proliferation of technology to Japanese, West European and socialist economies may be weakening the U.S. bargaining position as a supplier of technology to newly industrializing countries and in trade negotiations with these countries; and

6) Technological partnerships with industrial enterprises in developing countries could be mutually beneficial.

Behrman, Jack N., and Wallender, Harvey W. Transfers of Manufacturing Technology Within Multinational Enterprises. Cambridge, Mass.: Ballinger Publishing Company, 1976.

This book consists of case studies of transfers of manufacturing technology abroad among members of multinational enterprises (i.e., affiliates wholly-or predominantly-owned by the parent). These are studies of Ford's transfers to South Africa and Taiwan, ITT's transfers to South Africa and Mexico, Pfizer's transfers to Nigeria and Brazil, and Motorola's transfers to Korea. There were similarities in these cases in that full technology transfers would have been unlikely without majority ownership. In each case, technical transfers were continuous, i.e., they occurred over the life of the association and over a wide range of activities.

Boretsky, Michael. "Trends in U.S. Technology: A Political Economist's View." American Scientist, 63, No. 1 (1975), 70-82.

After examining trade surplus data by product groups, the author concludes that since 1951 technological know-how has been the force behind U.S. trade successes, but that since 1971 this force has been getting weaker, contributing strongly to the deterioration in the U.S. trade position. Boretsky discusses what he perceives as the reasons for the loss of the U.S. technological advantage. He then illustrates his points with an examination of the electronics and communications equipment industry.

Cohen, Benjamin I., Katz, Jorge, and Beck, William T. Innovation and Foreign Investment Behavior of the U.S. Pharmaceutical Industry. Working Paper No. 101. New York: National Bureau of Economic Research, Inc., August 1975.

The authors offer detailed information on innovation and foreign investment in the pharmaceutical industry. They chose a sample of 22 drug companies in the United States with sales in excess of $70 million that first marketed at least four single entity (non-combination) drugs from 1963 to 1972. The authors analyze the data describing the new drug innovations. Drugs are assigned categories such as innovative or imitative. Time series analyses and cross-sectional analyses of the pharmaceutical firms' new sales and number of innovations were undertaken. It was found that those measures of innovativeness that were considered indicators of output, such as the ratio of innovative drug sales to total drug sales, were positively correlated with each other. They were also positively correlated with measures of the quality of new drugs, such as R&D expenditures per new drug or sales per new drug introduced. They were not related to the frequently used measures of innovativeness used as indicators of input, such as the ratio of R&D expenditures to sales, and were negatively related to such measures of R&D efficiency as R&D expenditures per dollar of sales of new drugs.

Kelly, Regina. Alternative Measurements of Technology-Intensive Trade. Office of Economic Research Staff Economic Report 17 (OER/ER-17). Washington, D.C.: U.S. Department of Commerce, September 1976.

The main point of this study is that the U.S. position in technology-intensive trade (by 3 definitions set forth in the study) generally stagnated or declined between 1968 and 1972, but since 1972 it has strengthened. The 3 definitions of technology-intensive trade are (1) DOC-1, Department of Commerce Number 1, identifies products as technology intensive if they are output of a "technology-intensive industry"; (2) NSF, a definition of the National Science Foundation which is similar to DOC-1; (3) DOC-2, Department of Commerce Number 2, which is product-based definition and is based on product rather than industry data. The study describes the differences in the criteria and coverage of the three different classification systems and notes their limitations. It also examines particular aspects of the relationship between technology and trade performance.

LaCroix, Robert, and Scheuer, Philippe. "L'Effort de R&D, l'Innovation et le Commerce International." Revue Economique, 27, No. 6 (1976), 1008-29.

Using aggregate OECD data, the authors found a significant positive correlation between relative rates of innovation (estimated as relative levels of total R&D expenditures) and export competitiveness in 5 out of 9 countries, including the U.S. They also found that the elasticity of exports to innovation efforts, i.e., the impact of R&D expenditures on export levels, does vary from sector to sector.

National Science Foundation. Report of the National Science Board. Science Indicators 1976. Washington, D.C.: Government Printing Office, 1977.

This publication gives indicators of research, inventions, and innovations by product by year. Funding agencies, development centers, fields of research, and government and private research funds through 1976 are presented. The numbers of scientists, engineers, Nobel prize laureates, and national expenditures for R&D are listed for the last decade and a half. The report is also concerned with the measures of some of the impacts and contributions of research and development.

National Science Foundation. Survey of Science Resources Series (NSF76-322). Research and Development in Industry 1974. Washington, D.C.: Government Printing Office, 1976.

This annual publication is a presentation of research and development funds by varying industries. The data include general characteristics of R&D funds over time and cross-sectionally. R&D is specifically stated to be federal, or company-financed, or industrial. The number of scientists and of personnel in other research occupations are broken out. Types of research

such as basic, energy, and pollution abatement, as applied by category (product field, industry, science, or source) are presented. Data tables show R&D by company, by SIC code, by geographic distribution, research field related to employment and net sales, and distribution of R&D funds, by major types of costs, such as wages, materials, percent of net sales, cost per R&D scientist, or engineer.

Teece, D.J. "Technology Transfer by Multinational Firms: The Resource Cost of Transferring Technological Know-how." Economic Journal, 87, No. 346 (1977), 242-61.

This study focuses on the cost aspect of technology transfers. It used data on 26 fairly recent international technology transfer projects. In the sample transfer costs ranged from 2 to 59 percent of total project costs. For the sample transfer costs averaged 19 percent of total project costs.

U.S. Department of Agriculture. Economic Research Service. Technology Assessment: Proceedings of An ERS Workshop, April 20-22, 1976. Washington, D.C.: U.S. Department of Agriculture, 1977.

This volume consists of the proceedings of an ERS workshop to facilitate interagency communications on technology assessment. Two methods for a transfer of technology (TT) study were proposed. One was a suggestion for measuring attitudes about TT. A "magnitude estimation" technique was presented whereby the recipient of a questionnaire would be asked to order a preference among policy alternatives. A second suggestion was the construction of an input-output analysis showing modification of the cost structure of an economy or sector of the economy by a technological innovation.

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